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EFFECT OF WORK ON THE CALCIUM AND PHOSPHORUS RETENTION OF PERCHERON GELDINGS[1]

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REPORTS of studies concerning the mineral nutrition of horses and mules are few compared to those involving other species of farm animals. Rations deficient in calcium and phosphorus may be fed more commonly to horses and mules than realized and, either directly or indirectly, may be the cause of certain diseases and unsoundnesses prevalent in the equine population. Furthermore, nothing is specifically known regarding the requirements of this species for calcium and phosphorus during work, as a review of the literature will reveal.

During the past 40 years, relatively few reports have been published concerning the calcium and phosphorus requirements of horses. Some have been based upon requirements of species other than the equine, while others are the result of actual feeding experiments with horses. After reviewing the work of other investigators, Schmidt (1940) estimated that 12 grams daily of both calcium and phosphorus will adequately meet a horse's requirements for these elements. Mitchell and McClure (1937) estimated that Percherons weighing between 400 pounds and 1600 pounds need 13.5 and 13.6 grams of dietary calcium and phosphorus, respectively, per animal daily. Data by Ingle (1907), Niimi and Aoki (1927), Sturgess (1927), and Kintner (1940) indicate that it is as important to supply calcium and phosphorus in the proper porportion in the horse's ration as it is to supply them in adequate amounts. Existing data are summarized in table 1. These data show that the amounts of calcium and phosphorus fed per horse per day ranged from 1.5 to 58.2 and 5.28 to 47.62 grams, respectively. The calcium to phosphorus ratios ranged from 1:0.2 to 1:9.2. However, in those cases which appeared to be normal as indicated by positive calcium and phosphorus balances or by good health and gain in weight, the amounts of calcium fed ranged from 14.8 to 32.2 grams, the amount of phosphorus from 12.71 to 24.5 grams, whereas the calcium to phosphorus ratios ranged from 1:0.5 to 1:1.3.

None of the foregoing citations reported any data pertaining to the effect of work upon the calcium and phosphorus metabolism of horses. Experimentation in this direction should yield data leading eventually to further research directed toward a better understanding of the causes of certain nutritional diseases of horses, more particularly those associated with anatomi-

[1] Journal Paper No. J-1042 of the Iowa Agricultural Experiment Station. Project No. 473.
[2] Abstract of part of senior author's doctoral thesis.

TABLE 1.—SUMMARY OF STUDIES RELATING TO THE CALCIUM AND PHOSPHORUS REQUIREMENTS OF HORSES

Grams per day per horse		Ca:P ratio	+ or − Bal.		Weight of horse	Remarks	Reported by—	Year
Ca	P		Ca	P				
grams	*grams*				*pounds*			
36.38	11.74	1:0.3	+	−	895.2	Growing horse	Tangl	1902
36.72	11.74	1:0.3	+	−	974.6	Growing horse	Tangl	1902
27.23	24.50	1:0.9	+	+	893.0	Growing horse	Tangl	1902
27.44	24.50	1:0.9	+	+	959.2	Growing horse	Tangl	1902
37.46			+				Von der Heide et al	1916
98.20			−				Von der Heide et al	1916
4.07	19.25	1:4.7	−	+		Fed oats only	Scheunert	1922
18.67	23.23	1:1.2	+	+	833.0		Scheunert et al	1923
11.67	15.94	1:1.4	+	−			Scheunert et al	1923
19.87	16.17	1:0.8				Control ration	Sturgess	1927
13.60	16.17	1:1.2				Slight osteo. fib.[d]	Sturgess	1927
13.60	33.20	1:2.4				Osteo. fib.[d]	Sturgess	1927
1.50	12.00	1:8.0				Fed barley only, osteo. fib.[d]	Niimi and Aoki	1927
2.60	20.70	1:8.0				Fed barley only, osteo. fib.[d]	Niimi and Aoki	1927
2.58	20.69	1:8.0				Osteomalacia in 4 months	Niimi and Aoki	1928
20.00	18.16	1:0.9				No osteomalacia	Niimi and Aoki	1928
35.01	18.35	1:0.5			862.0[a]	Osteomalacia improved	Kintner and Holt	1932
12.15	18.79	1:1.5			790.0	Osteomalacia not changed	Kintner and Holt	1932
22.58	18.79	1:0.8			836.0[b]	Osteomalacia improved	Kintner and Holt	1932
24.30	15.73	1:0.6			888.0[b]	Osteomalacia improved	Kintner and Holt	1932
24.30	37.14	1:1.5			834.0[b]	Osteomalacia not changed	Kintner and Holt	1932
12.22	12.71	1:1.0			—[c]	No osteomalacia	Kintner and Holt	1932
28.84	5.28	1:0.2	−	+	606.0	Fed hay only 5 days	Bang and Dahm	1934
3.77	34.86	1:9.2	−	+	606.0	Fed bran only 5 days	Bang and Dahm	1934
28.28	47.62	1:1.7	−	+	606.0	Fed bran & $Ca_3(PO_4)_2$ 5 days	Bang and Dahm	1934
14.80	19.60	1:1.3			850.0	Gained weight	Kintner	1940
14.80	19.60	1:1.3			1050.0	Gained weight	Kintner	1940
22.90	19.60	1:0.9			900.0	Gained weight	Kintner	1940
32.20	19.60	1:0.6			900.0	Gained weight	Kintner	1940

a Average, 9 horses. b Average, 5 horses. c 25 horses, no weights. d Osteodystrophia fibrosa.

cal malformations of osseous origin. While the authors were studying the nitrogen requirements of horses during rest and work, opportunity was afforded to study simultaneously their calcium and phosphorus requirements.

Experimental[3]

Calcium and phosphorus metabolism data were collected from two Percheron geldings. Bob was four and Mike five years old. They weighted 1683 and 1676 pounds at the beginning and 1629 and 1649 pounds at the end of the eight-week metabolism period, respectively. The experiment was of eleven weeks duration—two weeks preliminary maintenance, eight weeks metabolism, and one week post-work maintenance. The metabolism period consisted of maintenance, light, medium, and hard work periods, each of two weeks duration. Through the use of a specially constructed dynamometer, the amount of work performed by each gelding was quite readily controlled and measured. During the light, medium, and hard work periods the dynamometer was set at 100, 170, and 240 pounds tractive pull, respectively. Accordingly the horses developed 0.56, 0.93 and 1.27 horse power during the respective work periods.

The horses were fed a basal daily ration composed of three pounds of finely ground oats and twenty pounds of finely chopped timothy hay throughout the experiment. This ration proved adequate to maintain the weight of both horses during the preliminary and metabolism maintenance periods. During the work periods the gross energy of this basal ration was increased by adding sugar and dextrinized corn starch as the situation demanded. The unpalatability of these supplementing constituents made it impossible to avoid slight losses in weight as the trial continued. Iodized block salt (NaCl) was kept before the horses at all times. Distilled water was offered frequently and in amounts governed by their thirst. In the interest of accuracy and efficienty of operation the ingredients of the basal ration were weighed and bagged separately at the start of the experiment, immediately after total amounts of each feed sufficient to complete the experiment had been mixed thoroughly. Since each gelding was to receive one pound of oats during the morning, noon and evening feedings, and five, five and ten pounds of timothy, respectively, the oats was bagged in one pound and the timothy in five and ten pound quantities. Samples of oats and timothy were taken for chemical analysis as the feeds were bagged.

The collection of the excreta was accomplished by the use of specially made metabolism stalls and harnesses patterned after those designed by Howell (1931). Aliquot samples of both urine and feces were taken each day

[3] For more detail concerning materials and methods employed than reported here, the reader is referred to an earlier communication, Harvey, *et al.* (1939).

for compositing into weekly samples, which were preserved and analyzed subsequently for calcium and phosphorus according to a technique developed and reported by Morris, Nelson, and Palmer (1931).

Results and Discussion

The Calcium Balance

The weekly intake, output, and retention of calcium for each horse are shown in table 2.

TABLE 2.—WEEKLY CALCIUM BALANCES OF TWO PERCHERON GELDINGS DURING MAINTENANCE AND WORK

Period	Week	Calcium balance—Bob				Calcium balance—Mike			
		Intake, grams	Output, grams	Retention		Intake, grams	Output, grams	Retention	
				Grams	%			Grams	%
Maintenance	1	126	257	−131	−103.97	126	230	−104	− 82.54
	2	126	273	−147	−116.67	126	203	− 77	− 61.11
	Total	252	530	−278	−110.32	252	433	−181	− 71.82
Light work	3	126	251	−125	− 99.21	108	151	− 43	− 39.81
	4	118	197	− 78	− 86.10	126	245	−119	− 93.44
	Total	244	447	−203	− 83.20	234	396	−162	− 69.23
Medium work	5	118	186	− 68	− 57.63	122	217	− 95	− 77.87
	6	126	200	− 74	− 58.73	126	260	−134	−106.35
	Total	244	386	−142	− 58.20	248	477	−229	− 92.34
Hard work	7	122	186	− 64	− 52.46	122	227	−105	− 86.07
	8	126	178	− 52	− 41.27	123	210	− 87	− 70.73
	Total	248	364	−116	− 46.77	245	437	−192	− 78.37
Post-maintenance	9	126	151	− 25	− 19.84	126	177	− 51	− 40.48
Total for trial		1,114	1,878	−764	− 68.58	1,105	1,920	−815	− 73.76

Both horses were in negative calcium balance throughout the trial. This was undoubtedly due to the comparatively low percentage of calcium in each of the feeds fed. The timothy hay, the oats, and the corn starch analyzed .19 per cent, .06 per cent, and a trace of calcium, respectively. The calcium intakes of both horses were quite uniform when considered from week to week, period to period, and between horses.

The calcium output of Bob was greatest during the maintenance period, followed by a gradual decrease for each succeeding period including the week of post-maintenance. The behavior of Mike was somewhat different from that of Bob. Mike's greatest output of calcium occurred during the medium work period, whereas the calcium output was essentially the same during the hard work and maintenance periods.

When the calcium balance data are considered in toto, Bob retained more calcium than Mike, inasmuch as his negative retention was lower, i.e.,

TABLE 3.—WEEKLY PHOSPHORUS BALANCES OF TWO PERCHERON GELDINGS DURING MAINTENANCE AND WORK

Period	Week	Phosphorus balance—Bob				Phosphorus balance—Mike			
		Intake, grams	Output, grams	Retention		Intake, grams	Output, grams	Retention	
				Grams	%			Grams	%
Maintenance	1	128	172	− 44	−34.38	128	176	− 48	− 37.50
	2	128	218	− 90	−70.31	128	265	−137	−107.03
	Total	256	390	−134	−52.34	256	441	−185	− 72.27
Light work	3	130	202	− 72	−55.38	109	228	−119	−109.17
	4	123	177	− 54	−43.90	130	236	−106	− 81.54
	Total	253	379	−126	−49.80	239	464	−225	− 94.14
Medium work	5	124	187	− 63	−50.81	127	210	− 83	− 65.35
	6	131	197	− 66	−50.38	131	269	−138	−105.34
	Total	255	384	−129	−50.59	258	479	−221	− 85.66
Hard work	7	127	189	− 62	−48.82	127	180	− 53	− 41.73
	8	132	182	− 50	−37.88	129	318	−189	−146.51
	Total	259	371	−112	−43.24	256	498	−242	− 94.53
Post-maintenance	9	128	182	− 54	−42.19	128	179	− 51	− 39.84
Total for trial		1,151	1,706	−555	−48.22	1,137	2,061	−924	− 81.27

−764 grams compared with Mike's −815 grams. Expressed in percentage, Bob's retention was −68.58 per cent as compared with Mike's −73.76 per cent. Mike excreted 51 grams more calcium than Bob while consuming practically the same amount of calcium and doing practically the same amount of work. Figure 1 illustrates graphically the calcium balances of both horses.

The Phosphorus Balance

In certain respects the situation with reference to phosphorus was similar to that of calcium since the ration fed contained insufficient phosphorus to maintain positive phosphorus balances. The percentages of phosphorus in the oats, timothy hay, and corn starch were .33, .15, and .01, respectively. The total intake of phosphorus per horse during the trial was 34 grams larger

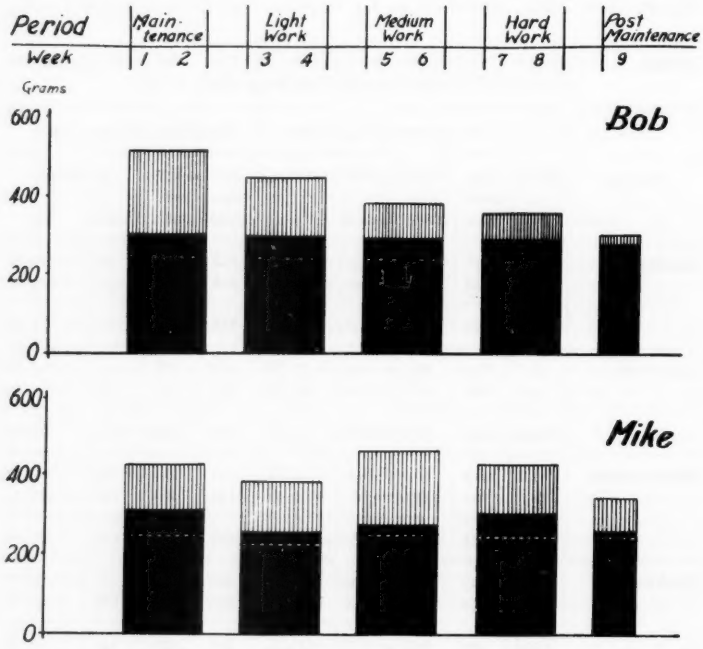

Figure 1. Calcium intake and output. Full length of each column indicates calcium output. Solid portion indicates output in feces, shaded portion indicates output in urine and portion up to dotted line indicates calcium intake.

than the total intake of calcium. Table 3 summarizes by weekly periods the intake, output, and retention of phosphorus for each horse.

Mike's output of phosphorus during the entire experiment was 355 grams greater than Bob's. Bob's total retention was −555 grams or −48.22 per cent, while Mike's was −924 grams, or −81.27 per cent. Figure 2 portrays graphically the phosphorus balances of both horses. The two horses were direct opposites when output of phosphorus by periods is considered. Bob's

greatest output occurred during the maintenance period and smallest during the hard work period, whereas Mike's greatest output occurred during the hard work period and smallest during the maintenance period.

The ratio of the average amount of calcium (18.00 g.) to phosphorus (18.29 g.) consumed daily by each horse during the maintenance period was 1:1.02. The maximum average amounts of calcium and phosphorus were

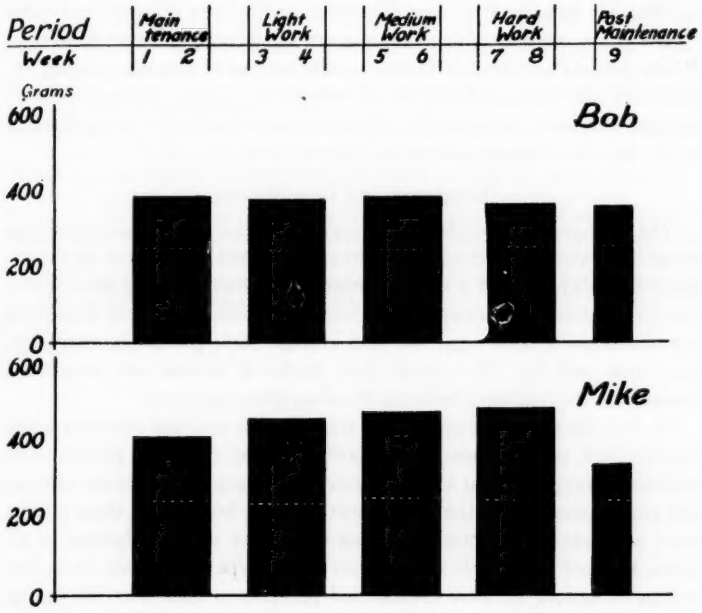

Figure 2. Phosphorus intake and output. Columns indicate output in feces. Output in urine was too small to picture in the chart. Portions up to dotted lines indicate phosphorus intake.

consumed by Bob during the second week of hard work during which his daily intake of calcium and phosphorus was 18 and 18.86 grams, respectively. The calcium to phosphorus ratio of the total feed consumed by Bob during this latter period was 1:1.05.

Scheunert, Schattka, and Weise (1923) fed a ration containing approximately the same amounts of these mineral elements and maintained an 833 pound horse in positive calcium and phosphorus balances. Kintner (1940) reported that a 900 pound horse fed daily a ration having a calcium to

phosphorus ratio of 1:0.8 and containing 22.9 grams of calcium and 19.6 grams of phosphorus remained in good health and gained weight. Apparently horses weighing 1680 pounds require more calcium and phosphorus than those weighing about one-half as much.

In this trial the horses behaved nearly alike with reference to calcium retention, but quite differently with reference to phosphorus retention. The mean retention of calcium (-751.5 ± 12.5 grams, 1 degree of freedom) was significantly different from zero. The mean retention of phosphorus (-687 ± 186 grams, 1 degree of freedom) was not significantly different from zero. When the data were analyzed further, using analysis of variance, a significant difference was found to have existed between the horses in phosphorus retention. However, no significant differences were found that are attributable to the reaction of the horses to the different levels of work.

Summary and Conclusions

The calcium and phosphorus retentions of a pair of Percheron geldings weighing about 1680 pounds each were determined as a part of an experiment that also included a study of nitrogen balances. During several consecutive metabolism periods of two weeks duration, each horse developed approximately 0, 0.56, 0.93, and 1.27 average horse power for more than four hours each day. The average daily intakes of calcium and phosphorus throughout the trial were between 18 and 19 grams per horse.

Neither the maintenance ration of three pounds oats and twenty pounds timothy hay, nor the same ration fortified during the work periods with additional energy as sugar and dextrinized starch supplied sufficient calcium and phosphorus to meet the requirements of these horses. Yet, these rations were adequate to maintain the horses in positive nitrogen balance at all times. It is not improbable when horses of this type and size are limited to rations containing no more calcium and phosphorus than were fed during this experiment that some of them would be receiving insufficient amounts of these elements to satisfy their needs.

During this experiment in which the total elimination of calcium and phosphorus always exceeded the total consumption of each, various amounts of work did not seem to affect measurably either the calcium or phosphorus balances of the horses.

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FRESHENING DATE CHANGES OF COWS IN IOWA DAIRY HERD IMPROVEMENT ASSOCIATIONS[1]

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EVIDENCE accumulated and published by McDowell (1922) indicates that cows which freshen in the fall and early winter produce more milk and butterfat and make a larger income over cost of feed than those which freshen in the spring and summer. This has been publicized widely through extension agencies and should have influenced dairy farmers to breed their cows for fall and winter freshening. Any effects of this publicity should show in a shifting of calving dates to the more profitable seasons.

Data and Discussion

The available records of the Iowa Dairy Herd Improvement Associations covering sixteen years (1926 to 1941 inclusive) disclosed a total of 153,610 cows with known calving dates. These were sorted by months and years and the percentage of the cows that freshened each month of each year was calculated. These are shown in table 1. These calvings were also regrouped to show the percentages that calved each season each year. This regrouping is shown in figure 1.

It appears from these data that only a little shifting of the percentages of cows calving each month has taken place during the sixteen years of this study. There was a gradual decline in the proportion of cows that calved in the winter and spring seasons during the years 1926 and 1933 (figure 1) while in these same years the percentages of cows that freshened in the fall were gradually increasing. From 1933 to 1937 the trends were reversed, as the percentages of cows that calved during these years increased slightly for the winter, increased more rapidly for the spring and declined rather rapidly for the fall. From about 1937 until 1941 the percentage of cows that calved in the fall increased again while the winter calvings decreased.

What is of more particular interest is that throughout this period the trend for the summer calvings has been slowly upwards (see figure 1) though this proportion of cows remained the smallest for any of the seasons through all the years studied. This is rather surprising for Cannon (1933) has shown that cows in the Iowa Dairy Herd Improvement Associations which calved during these months had a lower average annual milk and fat production than cows which calved during the fall and winter.

The distribution of the freshening dates with Iowa dairy cows is quite

[1] Journal Paper No. *J-1044* of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 31.

TABLE 1.—PERCENTAGE DISTRIBUTION BY MONTHS AND BY YEARS OF 153,610 CALVINGS OF COWS IN IOWA DAIRY HERD IMPROVEMENT ASSOCIATIONS

Year ending	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1926	11.3	9.1	9.8	7.0	5.2	3.7	3.8	5.0	10.4	11.5	12.5	10.6
1927	10.7	9.1	9.4	7.9	5.2	4.0	4.1	4.8	10.2	11.6	12.0	11.2
1928	10.2	9.4	9.8	6.4	5.5	4.0	4.8	5.5	9.2	11.6	12.9	10.7
1929	10.2	8.9	9.1	7.1	5.0	3.8	3.9	5.1	10.3	12.8	12.0	11.8
1930	10.2	9.4	8.6	6.0	5.7	4.6	4.2	4.9	10.9	12.0	11.9	11.7
1931	10.0	8.8	8.0	5.8	4.9	4.2	4.3	5.3	11.7	11.7	14.3	10.9
1932	9.1	8.4	7.3	4.9	5.1	4.4	4.5	6.1	12.7	12.8	13.4	11.4
1933	9.9	7.7	7.1	5.2	5.0	4.3	4.4	6.5	13.5	13.3	12.9	10.2
1934	9.8	7.7	7.1	5.4	5.9	3.6	4.5	6.1	12.7	14.0	11.9	11.4
1935	9.7	7.8	7.4	6.1	6.0	4.8	4.5	6.0	11.6	13.4	12.1	10.7
1936	9.8	8.5	8.6	6.0	5.8	4.7	5.4	5.5	10.9	12.4	12.1	10.4
1937	12.0	8.7	8.5	5.8	4.4	4.6	4.9	6.0	10.1	11.6	10.3	13.1
1938	9.6	9.7	9.4	5.3	4.8	3.4	5.6	6.6	9.3	10.5	12.0	13.8
1939	9.0	8.1	9.1	5.5	5.3	4.4	4.6	4.6	10.6	13.8	12.5	12.4
1940	10.0	8.3	7.1	6.1	5.9	3.3	4.6	8.0	12.4	12.0	10.9	11.5
1941	9.9	7.6	7.4	6.5	4.4	4.1	5.3	6.3	11.6	13.2	12.9	10.9
Weighted average	10.1	8.6	8.4	6.1	5.3	4.2	4.4	5.5	11.2	12.4	12.5	11.2

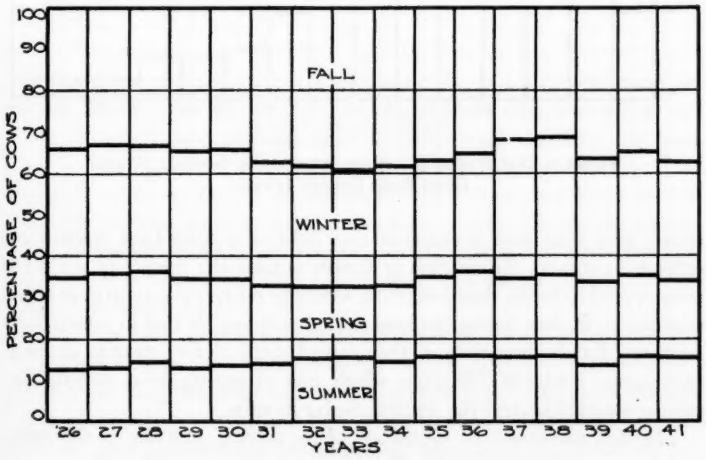

Figure 1. Percentage of cows (Iowa D.H.I.A.) that calved each season during 1926–1941.

different from those of the Hereford and Aberdeen-Angus breeds, for Cole and Rodolfo (1925) showed that over 43 per cent of these beef breeds calved during the spring months, while only about 17 per cent calved during the fall. These differences between dairy and beef cattle in season of calving indicate that calving time is partially controlled by herd owners, but the constancy of the percentages of dairy cows calving in the same month and

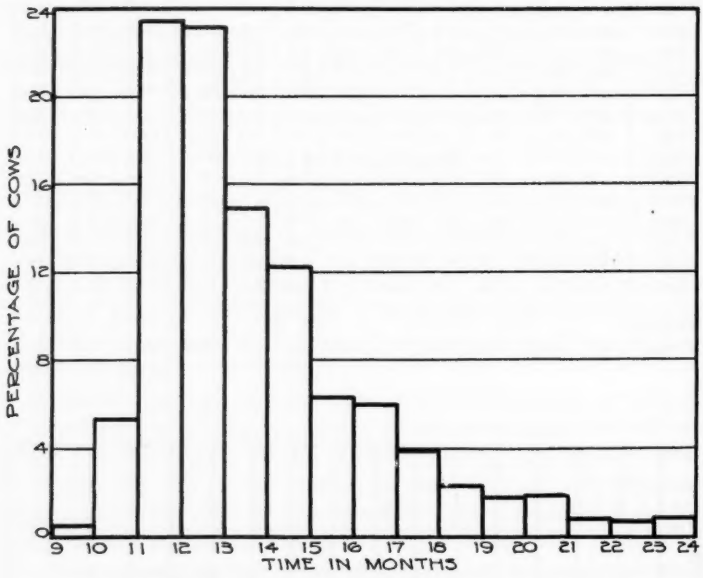

Figure 2. Distribution of calving intervals by monthly periods (Iowa State College cows).

season year after year is evidence that either the cows have reached an economic optimum distribution or factors outside the control of the herd owners tend to fix the distribution. It would be relatively easy to have cows continue to freshen during the same period each year as that in which they freshened for the first time, if they calved every twelve months as some recommend. Frequent difficulties which arise in settling cows prolong the calving interval beyond the desired twelve months.

The data permitted the calculation of the calving intervals[2] of the Iowa

[2] The estimated calving intervals were calculated by dividing the total cow days in each year (total cows X365 days) by the number of calvings that occurred during the same year.

D.H.I.A. cows for the sixteen years. Although small variations occurred from year to year they mostly fell close to the average for the entire period of 451 days (about 15 months). This is similar to the average calving interval of 446 days found in the Iowa State College herd for a nineteen year period.

The distribution of the calving intervals which made up the average was not obtainable from the data of the Dairy Herd Improvement Associations but should be similar to that found in the Iowa State College herd which is shown in figure 2. Most of the College cows calved in the twelfth and thirteenth months following their previous calving with descending numbers calving as the intervals became longer. Some cows did not calve until after an interval of two years or more.

Even if all heifers calved for the first time in the fall, the subsequent calv-

TABLE 2.—SEASONAL DISTRIBUTION OF ALL SUBSEQUENT CALVINGS OF 157 IOWA STATE COLLEGE COWS THAT CALVED FOR THE FIRST TIME IN THE FALL SEASON, AND OF ALL D.H.I.A. COWS

Season	Subsequent calvings, college cows		All calvings, D.H.I.A. cows	
	Number	Percentage	Number	Percentage
Winter	110	28.7	46048	30.0
Spring	77	20.0	30373	19.8
Summer	47	12.2	21700	14.1
Fall	150	39.1	55489	36.1
Total	384	100.0	153610	100.0

ings would be redistributed into other parts of the year if they followed the common calving interval pattern. The only available data from which this redistribution of later calvings could be determined was from the Iowa State College herd. In this herd there were a total of 157 cows which calved for the first time in the fall. As shown in table 2 these cows had a total of 384 subsequent calving, 150 of which occurred in the fall, 110 in the winter, 77 in the spring and 47 in the summer. This distribution of later calving is surprisingly similar to the distribution of all calvings of D.H.I.A. cows, which is shown in figure 1.

The fairly even distribution between seasons of the calving dates of the Iowa State College cows that calved for the first time as shown in table 3 is proof that no great effort was made to govern these calvings. With such "chance" breedings the distributions of the "subsequent calvings" and "all calvings" give patterns that are measurably different from the calving pattern of the D.H.I.A. cows. Considerably more of the College cows calved in the summer and less in the fall,

If no efforts were made by D.H.I.A. dairymen to control the freshening dates of their cows their trends would be towards an even distribution between seasons as occurred in the College herd. Iowa dairymen probably have attempted to obtain the advantages of seasonal influences by freshening their heifers for the first time in the fall. Failure to settle on first breeding after their fall calving, and perhaps other factors, prevented many cows from coming into full flow of milk again within the ideal 12-months interval. The

TABLE 3.—SEASONAL DISTRIBUTION OF ALL FIRST AND SUBSEQUENT CALVINGS IN THE IOWA STATE COLLEGE HERD

Season	First calving		Subsequent calvings		All calvings	
	Number	Percentage	Number	Percentage	Number	Percentage
Winter	183	28.2	350	26.0	533	26.7
Spring	137	21.1	328	24.3	465	23.3
Summer	139	21.5	291	21.6	430	21.6
Fall	189	29.2	378	28.1	567	28.4
Total	648	100.0	1347	100.0	1995	100.0

lengthening of the interval forced later calvings into other seasons of the year.

The fixity of the distribution of calving dates of the D.H.I.A. cows from year to year over a period as long as 16 years suggests that this is probably the most economical distribution for Iowa dairymen. Any attempt to increase the number of cows freshening during the fall and winter through lengthening the calving interval of those cows that calve in the spring and summer even though it may be desirable for high yield in the following lactation might reduce the total yield of the herd and profits.

Summary

Little change occurred from year to year in the percentages of cows in Iowa Dairy Herd Improvement Associations that calved in the different months and seasons. The average percentage distribution of freshening dates was found to be: winter, 30.0 per cent; spring, 19.8 per cent; summer, 14.1 per cent; and fall, 36.1 per cent.

The calculated average calving interval among Iowa D.H.I.A. cows was found to be 451 days which is similar to the calving interval of 446 days found in the Iowa State College herd over a 19-year period. Nearly one-half (48.3 per cent) of the Iowa State College cows had calving intervals of less than 13 full months. The intervals of the other cows ranged up to over 2 years in length.

One hundred fifty-seven Iowa State College cows that calved for the first time in the fall season had subsequent calvings that were distributed as follows: winter, 28.7 per cent; spring, 20.0 per cent; summer, 12.2 per cent; and fall, 29.1 per cent. This distribution was similar to that found among Iowa D.H.I.A. cows.

When no apparent effort was made to freshen cows for the first time in any one season as appeared to be true in the College herd, the distribution of the freshening dates was noticeably different from that found with D.H.I.A. cows, the greatest differences being in the percentages that calved in the summer and fall seasons.

Iowa dairymen evidently have made an effort to freshen their cows in the fall but calving intervals longer than twelve months cause some calving dates to shift to other seasons. Economic factors other than high milk yields probably hinder any shifting of cows whose calving dates occur in other seasons back to fall calving.

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GENETIC AND ENVIRONMENTAL CORRELATIONS BETWEEN THE GROWTH RATES OF PIGS AT DIFFERENT AGES[1]

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Introduction

EARLY growth rate in pigs is correlated with growth in subsequent periods. Presumably the association is due to the effects of genetic and/or environmental factors which act over relatively long periods of time. The extent to which growth genes with persistent effects operate in determining hereditary variations in growth rate is of interest in swine breeding research. Information of this kind is required to attain maximum accuracy in measuring breeding value and hence to make most efficient use of selection.

For example, if genes with effects of short duration were responsible for most of the hereditary variation, growth rate in one stage would be relatively independent of that in another stage, depending upon the duration of each stage and the interval between stages. According to this possibility most of the observed association between growth rates in the different stages must be due to the effects of persistent environmental circumstances. Consequently separate consideration might be given the different stages in measuring hereditary growth rate for the entire period.

Conversely, if growth genes with persistent effects are responsible for most of the hereditary variation, they would contribute to the observed correlation between gain in different stages. Growth rate in each period would contain information concerning hereditary growth rate in other stages. In fact, growth rate for a short period where hereditary variations are relatively large might even be a more accurate indication of hereditary growth rate over the entire period than growth rate from birth to market age. Consequently information about the kind of genes which influence growth rate is useful in planning a breeding program designed to increase the economic value of swine.

The authors have investigated the genetic and environmental relations which contribute to the gross correlations between growth rate in three 56-

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day periods from birth to 168 days and have attempted to apply the results in measuring hereditary growth rate with maximum accuracy.

Analytical Method

Each of the main sources which may cause variation in growth rate represents the sum of the effects of a large number of agencies which act simultaneously and more or less continuously during the growing period, so that the specific effect of any one source is not directly measurable. However each source may be visualized as a quantitative variable, the actual values for which correspond to the effects which that source has upon the growth rate of individual pigs. Accordingly, let growth rate for each individual pig be the sum of the three variables: (1) A genetic source (G), composed of the *average* effects of all genes which influence growth rate; (2) litter environment (L), comprising the effects of all environmental factors which influence the litter as a whole; and (3) a residual source (E), including the effects of dominance, epistasis and environmental factors peculiar to individual pigs. Then growth rate in the ith period is defined by the equation

$$X_i = G_i + L_i + E_i \qquad (1),$$

where each variable is considered as a deviation from the general mean. Thus variation in growth rate is the consequence of differences in one or more of the three sources. The variance [$V(\ )$] in growth rate in the ith period is

$$V(X_i) = V(G_i) + V(L_i) + V(E_i) \qquad (2),$$

provided the three sources are statistically independent.

The growing period can be divided into any number of more or less arbitrary intervals, the gain in each period being considered as a distinct quantitative trait with its own sources of variation. Then the covariance [cov $(\ )$] between the growth rate in the ith and jth periods is

$$\text{cov}\,(X_iX_j) = \text{cov}\,(G_iG_j) + \text{cov}\,(L_iL_j) + \text{cov}\,(E_iE_j) \qquad (3),$$

provided each source in the ith period is statistically independent of the other two in the jth period. The correlation between the effects of a source in different periods can be written from equations 2 and 3. For example, the correlation between hereditary growth rate (the genetic correlation) in the ith and jth periods is $\dfrac{\text{cov}\,(G_iG_j)}{\sqrt{V(G_i)\cdot V(G_j)}}$. Since these correlations are of particular interest, estimating the variances in equation 2 for each period and the covariances in equation 3 for each combination of periods is essential to the solution of the present problem.

The first step is calculating from the data the components of variance and

covariance attributed to (1) differences between sires, (2) differences between litters by the same sire and (3) differences between litter mates. The form of the analysis used is presented in table 1, along with the theoretical composition of the variance and covariance. The theoretical composition given in table 1 exemplifies the effect which a limited number has upon the sample variance and covariance as compared to those expected in a population of infinite size. The components of variance are additive, $V(P)+V(M)+V(S)$ being the variance expected among pigs from different litters and by different sires. The same is true for the covariance.

In a population mated at random, the percentages of the additively genetic

TABLE 1.—THEORETICAL COMPOSITION OF MEAN SQUARES AND COVARIANCES

Source	Degrees of freedom	Mean square	Covariance
Total	$mnk-1$	$V(P_i)+\frac{k(nm-1)}{nmk-1}V(M_i)$ $+\frac{mk(n-1)}{nmk-1}V(S_i)$	$\text{cov}(P_iP_j)+\frac{k(nm-1)}{nmk-1}\text{cov}(M_iM_j)$ $+\frac{mk(n-1)}{nmk-1}\text{cov}(S_iS_j)$
Between sires	$n-1$	$V(P_i)+kV(M_i)+mkV(S_i)$	$\text{cov}(P_iP_j)+k\,\text{cov}(M_iM_j)$ $+mk\,\text{cov}(S_iS_j)$
Between litters by the same sire	$n(m-1)$	$V(P_i)+kV(M_i)$	$\text{cov}(P_iP_j)+k\,\text{cov}(M_iM_j)$
Within litters	$mn(k-1)$	$V(P_i)$	$\text{cov}(P_iP_j)$

variance represented in $V(P)$, $V(M)$ and $V(S)$ are 50, 25 and 25, respectively. In the partially inbred lines from which the data were taken, most of the sires used each season were from different lines and were mated to females in the same line. Consequently the genetic contribution to $V(S)$ is larger, while that to $V(M)$ and to $V(P)$ is smaller than expected in a random mating system. According to formulae developed by Dickerson (1941) and to the inbreeding which has taken place, it seems probable that about 40 per cent of the additively genetic variance is represented in $V(S)$ and in $V(P)$, while $V(M)$ contains the remaining 20 per cent.[3] The genetic covariance is distributed in the same manner as the additively genetic variance. Since all

[3] This distribution of the genetic variance is an estimate based on the specific amount of inbreeding which has occurred in the North Platte swine herd. The exact distribution of the variance due to dominance deviations and epistatic (non-additive) gene interactions depends upon several factors the importance of which cannot be measured (the prevalence of dominance and epistasis, gene frequency, the degree of dominance and the particular types of non-additive interactions). According to Fisher (1918) and Wright (1935), most of the variances from these sources appears in $V(P)$.

litters were treated as nearly alike as was practical, $V(S)$ and cov (S_iS_j) may be assumed entirely due to genetic differences between sires.

Based on the above assumptions, estimates of the components of variance (equation 2) and of covariance (equation 3) were derived as follows:

Variance	*Covariance*
$V(G)=2.5V(S)$	cov $(G_iG_j)=2.5$ cov (S_iS_j)
$V(L)=V(M)-0.5V(S)$	cov (L_iL_j) = cov $(M_iM_j)-0.5$ cov (S_iS_j) (4).
$V(E)=V(P)-V(S)$	cov (E_iE_j) =cov $(P_iP_j)-$cov (S_iS_j)

Results

A description of the data and the general management of the swine herd from which the data were collected is given elsewhere (Baker, Hazel and Reinmiller, 1943).

The results of the analysis of variance and covariance for the gain in the three 56-day periods are summarized in table 2. The gains in the three periods

TABLE 2.—ANALYSIS OF VARIANCE AND COVARIANCE FOR GAINS IN THREE 56-DAY PERIODS

Source	Degrees of freedom	Mean squares			Covariances		
		X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3
Intraseason total	986	38.8	156.0	242.1	34.0	15.6	106.3
Between sires	54	131.8	574.7	669.7	154.2	86.0	331.4
Between litters by the same sire	197	93.7	287.3	408.7	80.1	40.7	139.5
Within litters	735	17.3	90.1	166.0	12.8	3.7	80.9

are designated X_1, X_2, and X_3 according to the age at which they occur. These data were analyzed on an intraseasonal basis (the differences due to the eight seasonal means being eliminated) so that the degrees of freedom for the intraseason total and for between sires in the same season were reduced by seven.

Agencies affecting the litter as a unit caused highly significant variation in gains for each period, as evidenced by the much larger size of the mean square between litters by the same sire as compared to that between litter mates. Some variation, but less extreme, was caused by differences between sires. The mean square between sires in the same season (using the mean square between litters by the same sire for error variance) was significant in the second and third periods and was almost significant ($F=1.40$) in the first.

The gross correlations between gains in the three periods are $r_{12}=.437$, $r_{13}=.161$ and $r_{23}=.547$ (from table 2). Since these three correlations are highly significant, one or more of the main sources of variation must contribute significantly to the covariation between periods. The present analytical problem is that of reducing these correlations into the relations existing between the genotypic and environmental effects which are responsible for the observed variation in the different periods.

The variance for each period and the covariance for each combination of periods in table 2 was analyzed into the three components of variation or

TABLE 3.—COMPONENTS OF VARIANCE AND COVARIANCE ATTRIBUTED TO DIFFERENCES (1) BETWEEN SIRES (S), (2) BETWEEN LITTERS BY THE SAME SIRE (M) AND (3) BETWEEN LITTER MATES (P)

Period	$V(S_i)$	$V(M_i)$	$V(P_i)$	Combination of periods	cov (S_iS_j)	cov (M_iM_j)	cov (P_iP_j)
1	2.38	19.98	17.27	1:2	4.62	17.56	12.75
2	17.93	51.18	90.09	1:3	2.83	9.63	3.71
3	16.28	63.23	166.01	2:3	11.98	15.25	80.92

covariation indicated in table 1. Although the exact values for these components of the variance and covariance are of little interest in themselves they are presented in table 3 as an essential step in the analysis. In these data, the number of pigs per litter (k) was 3.838, and the number of litters per sire (m) was 4.177.

The components in table 3 were used to derive the hereditary and environmental variances and covariances as indicated in equation 4. These latter are given in table 4 for the three periods. The first figure in each row is the variance for the source and period indicated by the row and column. Figures other than the first in each row are covariances. For example, $V(G_1)=5.95$ and cov $(G_1G_2)=11.55$. The phenotypic variances and covariances correspond to those for the intraseason total shown in table 2. Since each phenotypic estimate is the sum of the genetic and the two environmental components, it is slightly larger than the corresponding estimate in table 2 because of the restriction imposed by limited sample size.

Figure 1 presents a diagram of the genetic and environmental sources presumed to cause variation in gain in each period and of the relations between these sources which cause the observed correlation between gain in different periods. The quantitative importance of each source in causing variation is represented by path coefficients[4] while the relations between

[4] Specifically, the path coefficient is that fraction of the standard deviation of the dependent variable for which the designated factor is directly responsible (Wright, 1934).

each source in different periods is represented by correlation coefficients. The values for the correlations and path coefficients in figure 1 were calculated from the estimates given in table 4. The curved lines represent correlation

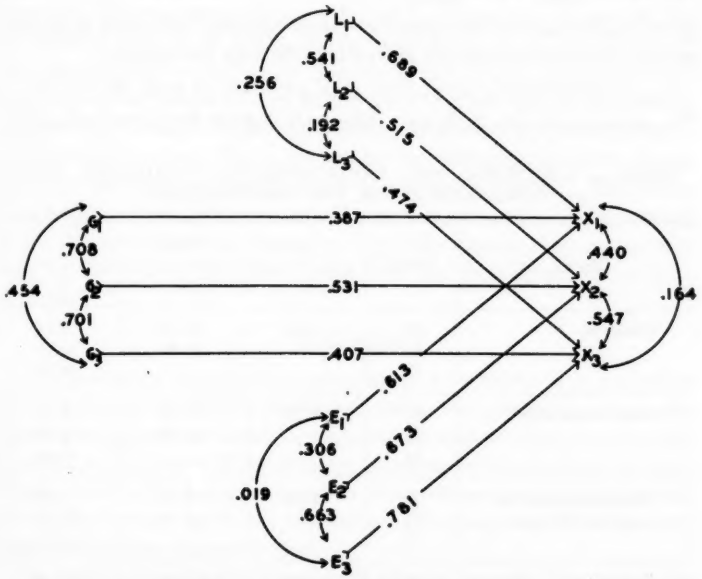

Figure 1. Path coefficient diagram to illustrate the genetic and environmental relations presumed to underly the observed correlation between gain in the three periods. X_1, X_2 and X_3 = gain in periods 1, 2 and 3, respectively. L_1, L_2 and L_3 = litter effect in the three periods. G_1, G_2 and G_3 = genotype for gain in the three periods. E_1, E_2 and E_3 = dominance and epistatic deviations and environment peculiar to individual pigs in the three periods. The straight lines represent path coefficients. The curved lines represent correlation coefficients.

coefficients. Each was calculated by dividing the appropriate covariance by the square root of the product of the two corresponding variances from table 4. For example, the genetic correlation is

$$r_{G_1G_2} = \frac{\text{cov}\,(G_1G_2)}{\sqrt{V(G_1)\cdot V(G_2)}} = \frac{11.55}{\sqrt{5.95\cdot 44.82}} = .708.$$

The straight lines represent path coefficients, the direction of influence being indicated by the arrow. Each path coefficient was calculated by dividing the square root of the variance for a given source by the square root of

the phenotypic variance from table 4. For example, the path from G_1 to $X_1 = \sqrt{\frac{V(G_1)}{V(X_1)}} = \sqrt{\frac{5.95}{39.63}} = .387$. Each of the gross correlations in figure 1 is the sum of three chains of causal relations, each chain being the product of one correlation and two path coefficients. For example,

$$r_{X_1X_3} = (.689)(.256)(.474) + (.387)(.454)(.407) + (.613)(.019)(.781) = .164.$$

The gross correlations in figure 1 differ only slightly from those calculated

TABLE 4.—GENOTYPIC AND ENVIRONMENTAL VARIANCES AND COVARIANCES FOR THE THREE PERIODS

Source	Period	Period		
		1	2	3
Genotype	G_1	5.95	11.55	7.07
	G_2		44.82	29.95
	G_3			40.70
Litter environment	L_1	18.79	15.25	8.22
	L_2		42.22	9.26
	L_3			55.09
Environment peculiar to the individual	E_1	14.89	8.13	0.88
	E_2		72.16	68.94
	E_3			149.73
Phenotype	X_1	39.63	34.93	16.17
	X_2		159.20	108.15
	X_3			245.52

from table 2 (.440, .164 and .547 as compared to .437, .161 and .547, respectively).

Several points in figure 1 appear sufficiently important to deserve comment. First, heredity plays a relatively minor role in causing variations in growth rate, particularly in the first and third periods. The heritability of gain (the path coefficients squared) is .15, .28 and .17 in the three periods, leaving 85, 72 and 83 per cent of the observed variance to be attributed to environmental circumstances. Second, the genetic correlations are generally larger than the corresponding environmental correlations. Consequently heredity exerts a less *important* but more *constant* influence upon growth over the entire period than do environmental circumstances. Third, the genetic correlations between the gains in the two adjacent periods are considerably higher than that between the periods separated by 56 days.

Presumably these points would be true regardless of the number or length of arbitrary periods used.

The importance of litter environment in causing variation in growth rate decreases with age, whereas that of environment peculiar to individual pigs increases. The correlation between E_1 and E_3 is very low in view of the relationship between E_1 and E_2 and between E_2 and E_3. Evidently the environmental factors which cause variation in the growth rate of individual pigs early in life persist into the second period but not into the third. Since $r_{E_2E_3} = .663$, the factors which begin operating in the second period are quite important in the third. This is not true for the environmental factors which influence the litter as a whole. Since $r_{L_1L_3}$ is larger than $r_{L_2L_3}$, the effects which operate in the first period must be more important in causing variation in the third period than in the second. The differences in these correlations may be due to sampling errors; hence their biological significance is questionable.

Application

The permanent improvement accomplished by selection is in proportion to the accuracy with which genetic differences among animals can be recognized. Since genotypes cannot be evaluated directly, selection must be practiced for some estimate of the genotype based on measurable characteristics. Consequently the correlation between the genotype and the variable used as a basis of selection provides a logical basis for comparing the efficiency of different measures of genetic merit.

As indicated previously, the gains in different periods may vary in the extent to which they represent hereditary growth rate over the entire period of 168 days. Growth rate over the entire period is the sum of the gains in the three 56-day periods. Thus hereditary growth rate for the entire period is

$$G_t = G_1 + G_2 + G_3.$$

Consequently (from table 4),

$\text{cov}(G_tX_1) = V(G_1) + \text{cov}(G_1G_2) + \text{cov}(G_1G_3) = 5.95 + 11.55 + 7.07 = 24.57;$

$\text{cov}(G_tX_2) = 86.32;$

$\text{cov}(G_tX_3) = 77.72;$

and $V(G_t) = 24.57 + 86.32 + 77.72 = 188.61;$

whence

$$r_{G_tX_1} = \frac{\text{cov}(G_tX_1)}{\sqrt{V(G_t) \cdot V(X_1)}} = .284;$$

$r_{G_tX_2} = .498;$

and $r_{G_tX_3} = .361.$

Thus the correlations indicate that of the three 56-day periods the second is the most efficient in measuring hereditary growth rate for the 168-day period.

Perhaps the most logical measure of G_i is

$$X_i = X_1 + X_2 + X_3,$$

where X_i is the gain for the entire period. Since

$$\text{cov}\,(G_i X_i) = V(G_i),$$

then

$$r_{G_i X_i} = \frac{V(G_i)}{\sqrt{V(G_i) \cdot V(X_i)}} = \sqrt{\frac{188.61}{762.85}} = .497.$$

An additional measure is the multiple regression equation

$$I = b_1 X_1 + b_2 X_2 + b_3 X_3,$$

where the b's are regression coefficients so chosen that the sum of squares of the deviations of I from G_i are a minimum. The simultaneous equations to be solved are

$$b_1 V(X_1) + b_2 \text{cov}\,(X_1 X_2) + b_3 \text{cov}\,(X_1 X_3) = \text{cov}\,(G_i X_1),$$
$$b_1 \text{cov}\,(X_1 X_2) + b_2 V(X_2) + b_3 \text{cov}\,(X_2 X_3) = \text{cov}\,(G_i X_2),$$
$$b_1 \text{cov}\,(X_1 X_3) + b_2 \text{cov}\,(X_2 X_3) + b_3 V(X_3) = \text{cov}\,(G_i X_3).$$

The estimates required for the solution of these equations are given above or in table 4. The multiple regression equation turns out to be

$$I = .064 X_1 + .130 X_2 + .038 X_3,$$

and

$$R_{G_i \cdot X_1 X_2 X_3} = r_{G_i I} = .516.$$

Recapitulating, the multiple regression equation gives the most accurate estimate of G_i, followed rather closely by gain in the second period and by gain over the entire period.

In the above comparisons it was assumed that change in any period was equally desirable. In practice, gain in one period may have more economic value than that in another period because of the extent to which it reflects greater economy of food utilization or more desirable carcass composition. This situation can be met by redefining G_i so that

$$G_i = a_1 G_1 + a_2 G_2 + a_3 G_3,$$

where the a's represent the economic values for the corresponding genotypes.

Discussion

From the practical view, the subdivision of the growing period for the purpose of measuring hereditary growth rate more accurately is of questionable value. The multiple correlation (.516) based on gains in the three 56-day periods is only 4 per cent larger than that based on gain over the entire period (.497). However, a subdivision might easily be justified if improved

growth rate in one period were considered more desirable than in another. In this event, similar analyses for swine herds differing in genetic background and under different systems of management would be needed to test the general applicability of these results.

This study yields some rather pertinent results in regard to the selection of boars as it is generally practiced. Weaning weight (usually at about 56 days) is often used as a measure of growth rate in making initial selections. Final selections are based on weight at about 180 days of age, after the normal growth of many boars is disturbed by sexual development. Weight at 56 days is probably not a good measure of hereditary growth rate since gain from birth to 56 days is a poor measure ($r_{G_i X_1} = .284$). Gain from 56 to 112 days ($r_{G_i X_2} = .498$) is probably a more accurate measure in boars than gain over the entire period ($r_{G_i X_t} = .497$, for barrows and gilts) because it occurs before puberty. Consequently the use of gain from 56 to 112 days in selecting boar pigs is a promising alternative to the usual method. Most of the initial selection at 56 days could be eliminated so that some good individuals would be saved. Castration at 112 days is little more difficult than at earlier ages, and all boars except those to be used could be castrated then.

Several methods of calculating growth rate have been proposed by different investigators. Gain in live weight (in pounds) during constant age periods was used in the present study because of its simplicity and directness, because gain in the different periods is directly additive and because it corresponds to the measures most widely used in swine breeding. The results reported herein may not hold for other methods of calculating growth rate.

Summary

The gross correlations between the gains in three 56-day periods from birth to 168 days were analyzed. The genetic and environmental relations presumed to underly these correlations are shown in figure 1.

The genetic variance constituted only a small fraction of the observed variance in each of the three periods (15, 28 and 17 per cent, respectively). However, the genetic correlations were larger than the corresponding environmental correlations, indicating that genes with persistent effects were responsible for much of the genetic variation. Consequently heredity has a less important but more constant influence upon growth rate than either of the environmental sources.

The genetic correlations between the gain in adjacent periods were considerably larger than that for the two periods separated by 56 days.

Five possible measures of hereditary growth rate for the 168-day period were compared. A multiple regression equation based on gain in each 56-day period was about 4 per cent more accurate than gain from 56 to 112 days or

gain from birth to 168 days. Gain from birth to 56 days and from 112 to 168 days were not efficient measures.

The possibility of using gain from 56 to 112 days as a measure of hereditary growth rate in selecting boar pigs is suggested.

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THE DEVELOPMENT OF AN INBRED LINE OF SWINE (MINN. NO. 1) FROM A CROSSBRED FOUNDATION[1]

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THERE is nothing new in developing a breed or strain of livestock from a crossbred foundation; in fact, it is difficult if not impossible to find a breed that does not rest on a crossbred foundation. In most instances the original crosses were made to gain immediate benefits in commercial production. Subsequent generations were also produced with economy of commercial production in mind. The development of a breed was an afterthought. In the case of the Shropshire breed some of the foundation crosses were made late in the 18th century, but the first flock book was not published until 1884. Some of the first crosses that served as foundation stock for the Poland China breed were made early in the 19th century, and the first record associations were not formed until 1878. The younger breeds, such as Columbia sheep, Santa Gertrudis cattle, and Lamona poultry, have been developed more rapidly and with the distinct objective of developing superior strains from the crossbred foundations.

While the development of a new strain or breed from a crossbred foundation is not new, the application of selection based on actual performance and the immediate use of inbreeding in the development of the strain is new.

Materials and Methods

The method used in the development of this strain is essentially the same as that used so successfully during recent years by plant breeders. This method has come to be known among plant breeders as the *pedigree method*. The method is described by Hayes and Immer (1942).

The objects in this method are (1) to combine in a single strain a maximum of the desirable characters of both parental breeds and (2) to induce the recombination of genetic factors which will result in the production of new and desirable characters not found in either parent. In this instance the objective was to combine as much of the length of body and plumpness of ham of the Landrace with the red color, prolificacy, and milking ability of

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[2] The authors acknowledge contributions made during the first years of this experiment by R. L. Donovan and C. L. Cole, formerly Superintendent and Assistant Professor of Animal Husbandry, respectively, of the North Central Experiment Station. The authors also express their appreciation to Dr. W. A. Craft, Director of the Regional Swine Breeding Laboratory, Bureau of Animal Industry, for his interest, encouragement, and many helpful suggestions. The authors are Professor of Animal Husbandry, Assistant Professor of Animal Husbandry, and Superintendent of the North Central Central Experiment Station, respectively.

the Tamworth and at the same time, if possible, bring out through the recombination of genes an accumulation of still other desirable characteristics of the two breeds. In this case rapid and economical gains were sought after.

In brief the methods employed were: (1) the selection of two breeds (the Landrace and Tamworth) believed to possess characteristics desired and to be rather widely separated genetically; (2) the selection of foundation animals with as much individual excellence and background of performance as was possible; (3) breeding from within a closed herd; and (4) rigorous selection from the outset for factors affecting economy of production.

In the summer of 1936 animals were purchased as follows: A Landrace boar from the Bureau of Animal Industry, three Tamworth gilts from Iowa State College, and three Tamworth gilts from the University of Saskatchewan. The merit of the original selections is due to the courtesies of Mr. John Zeller, Prof. Arthur Anderson, and Prof. J. W. G. MacEwan of the institutions mentioned respectively. The most apparent weaknesses in the foundation animals were weak pasterns and spreading toes.

Six litters (48 pigs) of crossbreds were produced in 1937 from which three F_1 boars and 13 F_1 gilts were saved for breeding. Five of the original Tamworth sows were saved for a second year. With the objective of widening the genetic base two Tamworth gilts were purchased from the University of Alberta and a Landrace boar and four Landrace gilts were secured from the Bureau of Animal Industry in 1937. The individual merit of the animals purchased in 1937 was higher than that of those secured in 1936; in fact their merit was exceptionally high. Fourteen animals therefore comprised the foundation for the herd.

The breeding program for 1938 farrow was as follows:

13 F_1 gilts bred to 3 F_1 boars for F_2 litters
5 Tamworth females bred to F_1 boars for backcross litters
4 Landrace females bred to F_1 boars for backcross litters
2 Tamworth females bred to a Landrace boar for F_1 litters.

All purebred animals and all F_1 breeding stock farrowed in 1937 were marketed during the summer of 1938. Selection of breeding stock in 1938 was therefore restricted to the 1938 crop and made on the basis of performance. Of the four boars saved 3 were F_2 and 1 was a Tamworth backcross. Of the 39 gilts that farrowed litters in 1939, 3 were F_1, 17 were F_2, 7 were Landrace backcross, and 12 were Tamworth backcross animals.

The three items of performance that have received most weight in selections have been fertility, rate of gain from weaning to 200 pounds, and economy of gain. No attempt has been made to weight the factors affecting se-

lections. In order to provide more leverage in selecting for fertility, the plan of farrowing more litters than could be accommodated in test lots was initiated in 1939. Starting with 1939 from one-third to one-half of the litters farrowed have been culled at weaning on the basis of litter size. Final selection of animals raised in test lots was based almost entirely on rate and economy of gain. Conformation has received some consideration in that pigs that were long of leg and light of ham or pigs that possessed other obvious

TABLE 1.—PERFORMANCE OF THE MINN. NO. 1 LINE BY YEARS

Item studied	Year					
	1937	1938	1939	1940	1941	1942
Av. inbreeding coefficient	0	.07	.14	.19	.22	.24
Av. No. pigs born alive per litter	9.2	9.5	8.8	9.3	8.6	8.8
Av. No. pigs weaned per litter	8.0	7.7	7.1	7.0	6.8	7.1
Av. weaning wt.*	44	34	30	29	35	33
Av. 180 day wt.	239	225	229	248	229	248
Av. rate of gain, weaning to 200 lb. wt.	1.53	1.51	1.57	1.67	1.50	1.64
Av. feed per 100 lb. gain	308	358	315	302	307	306

* A likely explanation for the heavy weaning weight in 1937 is that feeding practices for the project were not standardized until beginning the post weaning period. In 1937 the sows and pigs were fed all the skimmilk they would consume through the nursing period.

defects were rejected regardless of their performance rating in growth rate, economy of gains, etc.

The Landrace is white and the white is dominant to the Tamworth red. While one of the objectives was to develop a colored strain, performance has always been the dominating factor affecting selection. In the case of females where a red animal and a white one were of apparent equal merit, the choice went to the red one. Since many more boars are produced than are used as breeders it was possible to make most rapid progress in color through the boars. A white F_2 boar was used in 1938, but all other boars have been red.

Experimental Results

A summary of the performance in this herd by years is presented in table 1. The data through weaning are on all the pigs in the line; the remaining data are on test lots only. Even with carefully standardized practices of feeding and management many environmental differences will occur between years, and for this reason the general trend through several years is of more significance than year to year differences. The high feed requirements of 1938 illustrate this point; 1938 was a very dry year and the lots were practically dry. The low rate of gain in 1941 also illustrates the point, for in

TABLE 2.—VARIANCE[1] WITHIN LITTERS OF RATE OF GAIN

Year	Breeding of swine			
	Minn. No. 1		Poland China	
	D.F.[2]	Variance	D.F.[2]	Variance[3]
1937	32	.0126	39	.0213
1938	113	.0205	160	.0159
1939	65	.0146	229	.0161
1940	135	.0151	248	.0154
1941	117	.0242	294	.0201
1942	163	.0130	—[4]	—

[1] The values recorded are weighted averages of variances within litters calculated separately for males and females. They were obtained in this way because sex differences would have contributed more to variance in one group than in the other.

[2] D.F. (degrees of freedom) in this case equal number of animals minus twice the number of litters including both sexes minus the number of litters containing animals of only one sex.

[3] Weighted average of the variance within litters of five separate lines.

[4] The 1942 variance is omitted because irregularities in gathering some of the data reduce its reliability for this purpose. The data are used in table 3, however, because these irregularities have a negligible effect on variance for the entire group.

that year hog cholera vaccination upset the performance of about one-half the litters; this it is believed also increased the variability in rate of gain for that year (tables 2 and 3). Taken as a whole the performance data indicate that the herd has about held its own in fertility and economy of gain but that perhaps some improvement has been made in rate of gain.

The variance within a herd such as this is interesting. The variance within litters in rate of gain is presented in table 2. The same table contains the variance within litters of five inbred lines of Poland China swine which were being developed during the same period. Table 3 contains summaries

TABLE 3.—VARIANCE[1] WITHIN LINES OF RATE OF GAIN

Year	Breeding of swine			
	Minn. No. 1		Poland China	
	D.F.[2]	Variance	D.F.[2]	Variance[3]
1937	46	.0172	54	.0361
1938	154	.0252	200	.0223
1939	104	.0253	334	.0243
1940	187	.0174	357	.0227
1941	162	.0304	391	.0290
1942	212	.0164	351	.0263

[1] The values recorded are weighted averages of variances calculated separately for males and females.

[2] D.F. in this table equal the number of animals minus twice the number of lines.

[3] Weighted average of the within line variance of five separate lines.

of the variance within the lines by years for this line and the five Poland China lines taken as a group. In 1941 the variance both within litters and within the line shows a sharp increase. That year the pigs were vaccinated in two groups and many of the animals in the second group suffered severe after effects of the vaccination. Some recovered rapidly and others did not. This was an environmental upset which reflected itself in lowered average rate of gain and increased variability in gain. Taken either within litters or within the line the Minn. No. 1 hogs have shown no more variance (perhaps less) in rate of gain than the Poland China hogs. This is in marked contrast to what has been generally stated regarding the breeding performance of crossbred hogs.

In color the hogs have shown more variability than would be found occurring within one of the pure breeds. White is a dominant color; hence the first year the hogs were all essentially white in skin and hair although a few pigs possessed small pigmented skin areas, and on close observation a slight reddish tint to the hair was recognizable. In 1938 about three-fourths of the pigs were white. Gradually the white has been replaced with red and the breeding herd now is basically red but a few individuals have some black spots.

There has been and still is some variability in type of ear, but gradually the drooping ear appears to be becoming fixed, although no attempt has been made to fix ear type.

The 1938 and 1939 crops appeared to be more variable in body conformation than those of other years. Some of this undoubtedly was accentuated by differences in color and type of ear; nevertheless, a few pigs had very short legs and others had long legs. Differences in body length also were apparent. In selection an attempt was made to cull extreme types but in most cases they were eliminated by the usual process of culling for performance. In spite of the above mentioned slight variations in type none of the hogs were off type sufficiently to result in selling for less than top market price on the public market. In fact, in most instances the hogs sold on the public market at a slight premium over the top price paid for other hogs on the same market on the same day.

Conformation and Carcass Qualities

The Minn. No. 1 hogs appear longer-bodied and shorter-legged than most American breeds of hogs; this is verified by body measurements of these hogs in contrast to those of five Poland China lines (table 4). The Minn. No. 1 hogs average over 1½ inches longer in body, about ⅔ inch shorter of leg, and about ½ inch less in depth of body.

A sample of 28 hogs were given a slaughter test in 1942 with results as

TABLE 4.—BODY MEASUREMENTS* OF MINN. NO. 1 AND POLAND CHINA SWINE (1941 AND 1942)

Line	Measurement			
	Length of body	Width of body	Depth of body	Length of foreleg
	inches	*inches*	*inches*	*inches*
P.C.-M.L.	39.79	10.21	14.26	11.37
P.C.-B.S., No. 1	40.46	9.96	14.37	11.91
P.C.-V.	39.96	10.69	15.10	13.08
P.C.-W.L.	39.67	10.71	14.98	13.32
P.C.-B.S., No. 2	40.27	10.65	14.99	13.56
Average of:				
P.C. lines	40.03	10.44	14.74	12.65
Minn. No. 1	41.67	10.89	14.30	11.97

* Corrected to 205 lb. weight.

indicated in table 5. The 28 hogs put through the test were taken from the males and females discarded for breeding purposes and from among these the selection of the 28 was based on uniformity of live weight rather than form.

The packers commented very favorably regarding the carcasses on thinness of skin, uniformity of side, uniformity of back fat, thickness of flank, and lightness of bone.

Relationship

As stated previously 14 animals entered into the foundation of the herd. An analysis of the young stock retained for breeding at the close of 1942 shows that only 6 of the 14 foundation animals have contributed to the animals now in the herd, and of these 6 only 3 have a high relationship to the existing herd. The relationship, calculated in terms of "percentage of blood," of the herd to the six foundation animals is given in table 6.

TABLE 5.—CARCASS DATA ON MINN. NO. 1 HOGS

Item studied	Number and averages
Number of animals	28
Average live weight, lb.	196
Dressing percentage, warm	81
Average thickness of back fat	
7th dorsal vertebra, inches	1.5
Thinnest point, inches	1.3
Thickest point, inches	2.0
Ham index	136

TABLE 6.—RELATIONSHIP ("PERCENTAGE OF BLOOD") OF MINN. NO. 1 HOGS TO FOUNDATION ANIMALS

Animals	Relationship
	per cent
18–2, first Landrace boar used	44
12–79, Tamworth female from University of Saskatchewan	19
1 of 36, Tamworth female from Iowa State College	23
9 of 36, Tamworth female from Iowa State College	3
13–16, Landrace female used in backcross	6
T74R, Tamworth female from University of Alberta and used in backcross	5

It is interesting that while the second Landrace boar was superior individually to the first Landrace boar, yet the herd today shows no relationship to him. In like manner the second two Tamworth gilts were superior as individuals to the first ones yet the herd now shows only a low relationship to one of them.

Discussion

Regardless of what in the future may happen to this line (among other things it may be wiped out by disease or it may deteriorate due to either negligence or inbreeding), the development of this line to date has introduced a new method of animal improvement that likely will be used extensively in the years ahead. The experiment has demonstrated that it is possible to proceed much more rapidly with purification from a crossbred foundation than has generally been assumed. The study has also demonstrated that F_2 and F_3 populations do not necessarily show a general decline in vigor or so wide a segregation in type and performance as to be undesirable economically. The opinion that the use of F_1 animals for breeding purposes necessarily results in wide segregation and a general decline in vigor is regarded by many, perhaps a vast majority, as established facts. It is little wonder that the above mentioned opinions are so well established, for similar views have been expressed by Davenport (1907), Mumford (1919), Harper (1920), Babcock and Clausen (1918), Winters (1925), Jones (1925), and Rice (1942). Both Babcock and Clausen (1918) and Mumford (1919), however, give evidence of foreseeing something of the benefits to be derived from the type of approach herein described. Babcock and Clausen state as follows: "It is an open question whether livestock associations may not find it conducive to advancement to provide some method for the infusion of new blood, particularly in breeds which are giving increased attention to performance standards." Mumford states, "Variations which appear as the result of crossing may be desirable or undesirable. . . . Such valuable mutations may be perpetuated by in-breeding and a new and valuable quality

sometimes secured in this way. This method is not practical for breeders of registered live stock under present conditions, but has been of great service to the breeders of plants."

It should be recognized, however, that the cross employed in this experiment probably was not as wide as many made by plant breeders. In the case of wider genetic crosses it is perfectly conceivable that many undesirable recombinations might occur. It is believed that the superiority of the foundation animals and the rigorous selection for performance were largely responsible for the lack of deterioration in F_2 and later generations. It is also believed that the rigorous selection practiced did much to keep segregation under control.

Anderson (1939) in a study of recombination points out that only a fraction of the possible recombinations are to be expected in the F_2 population. He suggests that a maximum of desirable recombinations may be induced by saving for breeding F_2 individuals some of which adhere to one parental type and some of which adhere to the other parental type. The method of procedure recommended by Anderson was practiced to a limited extent at least in the conduct of this experiment. Selection was based on performance and this resulted in the retention of some animals inclined toward the Tamworth type and others inclined toward the Landrace type during the first years of the experiment. This may have had some effect on bringing out further recombinations conducive to performance, for data in table 1 indicate that some improvement in rate of gain was made during the progress of the trial.

There can be little question but that a recombination occurred which resulted in satisfactory feet and pasterns. At any rate the foundation stock was weak in these respects and the present herd is very satisfactory in feet and pasterns.

The carcass data that have been gathered are meager but they indicate that the animals yield superior carcasses. The carcasses so far studied compare very favorably with the standards set by the Production Service (1941) of the Canadian Department of Agriculture for the Advanced registry for purebred swine.

No systematic study of the value of this line in crosses with other breeds has been made. A number of boars have been released to farmers for top crossing on other breeds and the farmers' reactions have been very favorable. Several crossed litters have been produced at the University and the resulting pigs have done very well. Hence there is some reason to suspect that this line of swine may possess genes not common to most American breeds and that some benefit is derived from using them in crosses.

The methods used in developing this line suggest many possibilities of

application to the advancement of animal breeding. *It is not at all improbable that several, perhaps many, of the inbred lines of swine now being developed in this country will cross to advantage and furnish foundation material for the development of new lines distinctly superior to the line herein described.* In fact, this is to be expected because the inbred lines are being purified for production, whereas the foundation for this line was selected before lines of that kind are available.

Summary and Conclusions

A cross was made between the Landrace and Tamworth breeds of swine. New breeding stock was then introduced and the second crop of pigs consisted of F_1, F_2, Landrace backcross, and Tamworth backcross individuals. From that time on the herd was bred from within.

The herd was founded with 14 animals derived from 4 different herds. Only 6 of the 14 have contributed to the ancestry of the stock now on hand, and of those 6 only 3 have made major contributions.

Rigorous selection for performance has been followed throughout the conduct of this experiment. The advance in inbreeding has not been rapid but in six years from the time of the first matings the coefficient of inbreeding has been raised to .24 which, with the exception of Shorthorn cattle, is about 2½ to 6 times as high as that of the breeds reported on by Lush (1937).

The wide segregation and general deterioration in performance generally believed to accompany the subsequent inbreeding of an F_1 population did not occur.

The performance of the herd and the quality of carcasses produced has been high.

The authors believe that this experiment points the way to a new method of animal improvement.

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RESPONSE OF PIGS GIVEN LARGE DOSES OF SALMONELLA CHOLERAESUIS TO SULFAGUANIDINE, NICOTINIC ACID, THIAMIN AND PYRIDOXINE[1]

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IN PREVIOUS experiments reported from this Station (Davis, Freeman and Madsen, 1940) and (Davis and Freeman, 1940) it has been noted that pigs suffering from an apparent deficiency of nicotinic acid developed what was designated necrotic enteritis.

The confusion centering in the use of the term "necrotic enteritis" has led the writers to consider the possibility of using a term more applicable to the etiology of the disease being considered. The deficiency disease due to a lack of nicotinic acid is similar in many respects to human pellagra and is often associated with a diet made up chiefly of corn. The similarity of human diets often associated with pellagra to those causing the deficiency disease in swine makes it seem logical that the disease of swine associated with a nicotinic acid deficiency and free from lesions due to Salmonella should be designated "swine pellagra," the term used by Madison, Miller and Keith (1938) in describing a condition of this nature.

The term "infectious necrotic enteritis" is also confusing because it applies to a pathological change of the intestine which may be associated with the invasion of more than a single type of pathogen. It is felt that a better term is probably "salmonellosis" when the disease described is due to salmonellae. In this paper salmonellosis refers to instances in which Salmonella choleraesuis was isolated from tissues of the infected swine.

Swine pellagra and salmonellosis of swine may occur concurrently or one predispose the animal to the other and this possibility must be kept in mind. In the experimental work reported in this paper an attempt was made to determine the relationships which may exist between the necrotic enteritis of swine pellagra and that of salmonellosis due to experimentally administered cultures of Salmonella choleraesuis.

In the previous experiments mentioned the swine pellagra syndrome responded rapidly when nicotinic acid was included in the ration. The necrotic enteritis present in the deficient animals frequently was associated with Salmonella. Presumably, though not certainly, this infection was secondary to the deficiency inasmuch as animals receiving nicotinic acid or a rich source of the vitamin, such as liver, did not develop the disease to the extent of those receiving no vitamin. Some evidence was obtained that if administered

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early in the course of salmonellosis, nicotinic acid enabled the pig to resist the attack of the organism. Later the response was questionable and was of no value if a generalized septicemia developed.

The difficulty of distinguishing between a deficiency disease and early salmonellosis caused the authors to search for some means of controlling infection with S. choleraesuis. It was hoped that in this way an uncomplicated nicotinic acid deficiency might be developed and evaluated both as a protection against the deficiency disease swine pellagra and in its relationship to salmonellosis.

The reports of Marshall, *et al.* (1940, 1941) on the drug sulfaguanidine and its use against bacillary dysentery suggested to the authors the possibility of using this drug to control Salmonella choleraesuis. Subsequently the report of Bornstein and Strauss (1941) on the action of sulfaguanidine against S. choleraesuis gave support to the results obtained.

Since the completion of these experiments Cameron (1942) and Kernkamp and Roepke (1942) have reported on the action of sulfaguanidine under conditions of veterinary practice. Their results indicate that sulfaguanidine has a definite bacteriostatic action against S. choleraesuis.

In the present experiment, therefore, sulfaguanidine[3] was given to the pigs to control any Salmonella infection. It was hoped that this drug, if it controlled the infection, would enable the pigs to make better use of the nicotinic acid. The ration in our hands has consistently produced a disease in pigs characterized by scours, development of coarseness of the skin, and a necrotic enteritis of the large bowel. Thiamin hydrochloride[4] (B_1) and pyridoxine hydrochloride[4] (B_6) were also included in the experiment in an effort to discover if these vitamins would have a beneficial effect.

The results have indicated that the sulfaguanidine and nicotinic acid were effective agents whereas the thiamin and pyridoxine were not.

Experimental Procedure

Thirty-six cross-bred and Poland China pigs which had been kept on cement platforms from birth were used in this experiment. They were weaned at 8 weeks of age and placed on experiment at 9 to 10 weeks of age. Until placed on experiment they received, in addition to the sow's milk, a ration of corn, wheat, tankage, alfalfa, and mineral, the nutritive ratio of which was approximately 4.5. The method of feeding the pigs individually was the same as described in a previous publication (Davis, Freeman and Madsen, 1940).

In order that statistical treatment might be applied to the results of the

[3] Made available through the courtesy of the Lederle Co.
[4] Made available through the courtesy of Merck and Co., Inc.

experiment the pigs were apportioned according to the factorial design which follows. Nine lots of four pigs each were selected at random, one from each of four weight classes. This was done so that, while randomized according to the 9 treatments, one pig in each lot was of similar weight to one pig in every other lot.

The basal ration fed to all lots is shown in table 1.

Of the nine lots set up eight were in a factorial design[5] with supplements noted below. The ninth lot (No. 5 in experiment) was given a supplement of liver.

The supplements given to the experimental lots are as follows:

Lot 1 C	Basal ration.		
" 2 CS	"	"	+sulfaguanidine.
" 3 CB	"	"	+thiamin (B_1)+pyridoxine (B_6).
" 4 CN	"	"	+nicotinic acid.
" 5 CL	"	"	+liver.
" 6 CSB	"	"	+sulfaguanidine+B_1+B_6.
" 7 CSN	"	"	+sulfaguanidine+nicotinic acid.
" 8 CBN	"	"	+B_1+B_6+nicotinic acid.
" 9 CSBN	"	"	+B_1+B_6+Nicotinic acid+sulfaguanidine.

Sulfaguanidine was given at the rate of 1 gram per pig daily for three consecutive days followed by three consecutive days without the drug and then repeated except that immediately following the administration of the culture of Salmonella the drug was given for five consecutive days.

Thiamin and pyridoxine were each given at the rate of 10 milligrams daily per pig.

Nicotinic acid was given at the rate of 100 mg. per pig daily and liver at the rate of 100 grams of either fresh or frozen ground liver.

From June 9, 1941 until June 23 the pigs were kept on the program described. June 23 each pig received a dose of 100 milliliters of a 36 hour beef infusion broth culture of Salmonella choleraesuis.[6] Temperature records for the succeeding 7 days demonstrated that of the 36 pigs only 3 failed to show a severe reaction to the culture as indicated by a sudden rise in body temperature, loss of appetite and severe diarrhea. All of these 3 were receiving sulfaguanidine; one each in lots 2, 6, and 7.

The pigs were continued on experiment until July 28 when all signs of the Salmonella infection in treated pigs had disappeared. Weight records were made weekly and averages of three consecutive days were used for beginning and final weights.

[5] Acknowledgment is made to Dr. W. D. Baten of the Mathematics Department of Michigan State College for his help in the statistical treatment of this experiment.

[6] The authors are indebted to Dr. J. F. Ryff and to Dr. H. J. Stafseth of the Michigan State College Bacteriology department for the culture of Salmonella and for the subsequent isolations from pig tissues.

Results and Statistical Treatment

The weight records for the week following the administration of the culture showed that most of the pigs lost weight but that the pigs receiving the sulfaguanidine lost less than the others, or actually gained weight. The analysis of variance showed for the weight gains or losses of the first week

TABLE 1.—COMPOSITION OF BASAL RATION

Ingredient	Parts	Per cent of ration
Corn	100	
Corn gluten meal	9	98.5
Dried skim milk	13	
Steamed bone meal	49	
Ground limestone	49	
Common salt	49	1.5
$FeSO_4$	3	
KI	.015	
Total		100.0

that there was a highly significant difference between the lots in favor of the sulfaguanidine. A summary of the analysis excluding the liver lot is shown in table 2.

The value of F for the effect of sulfaguanidine during the week following administration of the culture was nearly 3.5 times that required to show significance at the one per cent level.

Following the initial setback, after the culture had been given, the pigs began to show recovery and gains and all but two of the pigs, one each in lots 3 and 9, survived until the experiment was completed July 28.

An analysis of the total gains over the entire period is contained in table 2 using, however, only three animals in each lot to allow for the two lots which lost an animal, the animal eliminated in each lot having been chosen at random. An analysis of variance was also made eliminating first the heavy and then the light pig from each lot so that both extremes in weight difference might be considered. The results obtained gave F values of similar significance.

It will be noted that at this time both the sulfaguanidine and nicotinic acid showed significant differences in their favor.

Because it appeared that much of the benefit resulting from the use of sulfaguanidine was in preventing losses of weight immediately following the administration of culture an analysis was made of the gains over the period from June 30 to July 28 (table 2).

This analysis indicates that most of the beneficial effects of the sulfaguanidine were in protecting the pigs from the organism whereas most of

TABLE 2.—ANALYSIS OF VARIANCE OF CHANGES IN WEIGHT DURING VARIOUS PERIODS IN RELATION TO ADMINISTRATION OF SALMONELLA CHOLERAESUIS CULTURE

Source of variance	Weight changes following administration of culture (June 23–30)			Weight changes during entire period (June 9–July 28)			Weight changes during period beginning one week after administering culture (June 30–July 28)		
	Degrees of freedom	Sum of squares	Mean squares	Degrees of freedom	Sum of squares	Mean squares	Degrees of freedom	Sum of squares	Mean squares
Total	31	407.87		23	2414.8		23	1011.0	
Between lots	7	234.89	33.60**	7	1643.9	234.80**	7	525.7	75.10
Sulfaguanidine	1		190.13**	1		787.76**	1		222.04*
Nicotinic acid	1		21.13	1		700.92**	1		260.04**
(B_1+B_6)	1		8.00	1		0.30	1		26.04
Sul.+(B_1+B_6)	1		4.50	1		0.15	1		9.37
Sul.+nic. acid	1		3.13	1		31.05	1		1.04
Nic. acid+(B_1+B_6)	1		8.00	1		121.95	1		7.04
Sul.+nic. acid+(B_1+B_6)	1		0.00	1		1.76	1		0.04
Error (within lots)	24	173.00	7.20	16	770.9	48.18	16	485.3	30.33

* =significant at 5% level. ** highly significant at 1% level.

the beneficial effects of the nicotinic acid were in overcoming an apparent deficiency in the ration.

It should be noted that an analysis of variance was run on the starting weights and there was no significant difference between the lots.

In this experiment one lot of four pigs was included which received a supplement of ground fresh liver. These pigs all reacted to the culture with high temperatures and loss of weight. Subsequently however their recovery was quite rapid and by July 28 they showed weight gains over initial weight averaging 25.7 pounds compared with the next best lot, number 4, which averaged 24.2 pounds gain.

Discussion

The swine, on a ration which previously had shown evidence of a deficiency when fed to similarly treated pigs, were uniformly affected by the administration of a culture of Salmonella choleraesuis. The virulence of the culture was certainly not as severe as sometimes seen in the field. It was sufficiently so, however, to react on practically all of the pigs and the syndrome which has come to be considered typical of salmonellosis in this section of the country was definitely present. The organism was recovered from the swine which died and from slaughter samples of all the control animals.

From a casual observation of the pigs in the experimental pens it was evident that the swine receiving sulfaguanidine were resisting the Salmonella much better than those not receiving this drug. The typical scours disappeared rapidly and the pigs were off feed for a much shorter period than those not receiving sulfaguanidine. Because the writers were uncertain as to the dose of sulfaguanidine which would be necessary a dose of 1 gram per pig was selected and given with the other supplements as a suspension in water. The sulfaguanidine and supplements were given as a drench with the exception of the liver which was placed on the evening ration. The actual rate of sulfaguanidine dosage was between .04 and .07 grams per kilogram live weight and is considerably less than most of the doses used by Kernkamp and Roepke (1942). This amount had a very definite bacteriostatic effect as evidenced by the beneficial effect on the animals and the lack of Salmonella in the slaughter material at the end of the experiment.

The beneficial action of the nicotinic acid was not immediately apparent when the pigs were given the culture of S. choleraesuis. All the pigs receiving this vitamin showed a reaction to the culture. The deficiency of nicotinic acid in the ration, however, was remedied by inclusion of the vitamin as a supplement and after the initial setback due to S. choleraesuis the benefits from the vitamin became apparent in increased appetite and better gain and appearance of the pigs. The results obtained with thiamin and pyridoxine

failed to demonstrate any beneficial effect from these vitamins which could not be accounted for by chance alone.

An examination of the statistical treatment of gains (table 2) reveals that the only pigs which were able to withstand the salmonella culture were those receiving sulfaguanidine. A significant difference at the 1 per cent level was found in favor of this treatment. In the week following the administration of the culture only pigs receiving sulfaguanidine did not lose weight. That this was the principal beneficial effect of the sulfaguanidine becomes evident in a comparison of the various periods in table 2. In the analysis of variance treatment of the gain from initial to final weight it appeared that both sulfaguanidine and nicotinic acid showed a significant effect at the 1 per cent level. When, however, the gain between the period of first initial loss and final weight is considered it may be seen that most of the effect of the sulfaguanidine was due to the prevention of the initial loss whereas the nicotinic acid proved valuable in the period following the initial loss by promoting increased rate of gain.

The conclusion to be drawn from this result would appear to be that the sulfaguanidine was particularly valuable as a bacteriostatic agent but did not enable the pig to overcome the deficiency causing the pellagra-like syndrome. The results with nicotinic acid on the other hand indicate that this vitamin was needed in the ration and resulted in improved growth and protection from swine pellagra but did not have bacteriostatic properties.

The results of this experiment have demonstrated the possibility that sulfaguanidine may serve as a useful tool in controlling S. choleraesuis thereby enabling a delineation of the syndrome due to nicotinic acid. The experiment has left unsolved the question of whether the necrotic enteritis seen in swine pellagra is due to an infection by S. choleraesuis or is due entirely to a dietary deficiency as suggested by the English workers (Birch, *et al.*, 1937) and (McEwen, 1937 and Chick *et al.*, 1938). The possibility that pigs suffering from salmonellosis require a higher level of nicotinic acid in their diet and that pigs suffering from a nicotinic acid deficiency are more susceptible to S. choleraesuis invasion must also be considered further in future experiments.

The experiments of Bornstein and Strauss (1941) raise still another question in this connection. They found that S. choleraesuis was susceptible to the action of sulfaguanidine but that most other types of Salmonella did not respond to the action of sulfaguanidine either *in vitro* or *in vivo*. They used mice in their experiments and swine may react differently. The possibility, however, that salmonellosis caused by salmonellae other than S. choleraesuis might not respond to sulfaguanidine therapy cannot be ignored. This has practical importance in veterinary practice inasmuch as some of the worst

cases of salmonellosis in swine observed by the authors have been due to S. derby.

Summary

Thirty-six pigs were given a culture of Salmonella choleraesuis and also various combinations of supplements in an experiment designed to permit statistical analysis.

Sulfaguanidine was an effective drug in protecting the pigs from the S. choleraesuis.

Nicotinic acid did not prevent the pigs from reacting to the Salmonella but following an initial setback was effective in promoting rapid recovery and increased weight gains.

Vitamins B_1 and B_6 were not effective under the conditions of this experiment.

The results tend to substantiate previous observations that nicotinic acid is effective in preventing swine pellagra and in treating salmonellosis insofar as it enables the pig to maintain its body defenses but that it does not act as a bacteriostatic or bactericidal agent.

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EAR MEASUREMENTS IN RELATION TO PELT THICKNESS AND FUR CHARACTERS OF KARAKUL LAMBS

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Introduction

IN THE production of Persian lambskins the thickness of the leather is a highly important consideration. Pattern, luster, and size, tightness, and uniformity of curl are factors contributing to the natural beauty of this fur, and a light-weight leather is also especially desired by furriers in the manufacture of Karakul coats.

Because of the wide variation that occurs in the weight or thickness of pelts even from purebred Karakul lambs, the consistent production of the desired weight of leather is difficult. This is particularly true since the inheritance of the many characters contributing to the value of the pelt is not as yet clearly understood. The most logical approach to the problem of producing lamb pelts of uniformly light-weight leather is through the selection and mating of animals possessing this character. To practice this selection the breeder is in need of physical measures which may serve as an index to the thickness of the skin of each individual in his flock. The purposes of this study, therefore, were to illustrate methods of measuring ear skin thickness and ear length, and to determine their relationships to certain fur and pelt characteristics shown by the lambs at birth.

Adametz (1914) reported that Walta believed the ears are the best place to examine the skin for thickness. Adametz also states that a fine, firm, and soft lambskin can be predicted on the basis of the skin of the ears and jawbones of the adult. If the ear skin thickness of adult sheep is representative of the skin thickness over the body, this relationship might also exist in the lamb or other characteristics such as ear length might be associated with skin thickness in the Karakul. It was the opinion of Herre and Langlet (1936) that at birth the skin has already attained its final thickness and is only slightly changed thereafter, regardless of sex.

Material and Methods

One hundred sixty-six lambs born in the flock of Karakul sheep at the Beltsville (Md.) Research Center during the lambing seasons of 1937 and

[1] The cooperators participating in the project upon which this report is based are: D. A. Spencer, R. G. Schott, and C. G. Potts of the Bureau of Animal Industry, U. S. Department of Agriculture, and F. G. Ashbrook, C. E. Kellogg, and Thora M. Plitt Hardy of the Fish and Wildlife Service, U. S. Department of the Interior.

1938 were observed. Of this total, 68 lambs were purebred Karakuls and the remainder were grades (¾ to 63/64 Karakul) of Karakul × Blackfaced Highland and Karakul × Corriedale breeding.

The ears of the lambs were measured 2 to 3 days after birth. The thickness of the skin on the top of both ears of each lamb was measured with a paper gauge micrometer in hundredths of a millimeter. A fold of skin on the top of the ear, representing twice the actual skin thickness, was held between the thumb and forefinger and drawn between the two jaws of the

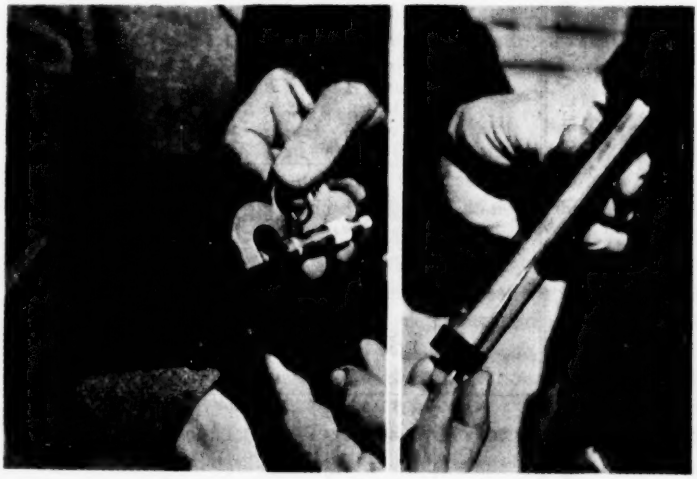

Figure 1. (Left) Measuring ear skin thickness with a paper gauge micrometer. (Right) Measuring ear length with a graduated transparent cylinder.

micrometer, as illustrated in figure 1. The jaws of the micrometer were given the same tension upon the skin in every case by means of the rachet stop adjustment. This stop adjustment was set with sufficient tension to make a positive contact with the skin without actually squeezing it but with enough contact so that a slight pull was required to draw the fold of skin from between the jaws of the micrometer. It was recognized that the variation in density of hair on the ears would introduce a slight error; however, it was believed that this error would remain fairly constant and not interfere with the desired results.

The length of the ears of each lamb was measured, as illustrated in figure 1, by means of a transparent cylinder 2.5 centimeters in diameter and 15 centimeters long, graduated in tenths of a centimeter from the bottom to the top.

TABLE 1.—RELATIONSHIPS BETWEEN EAR MEASUREMENTS AND PELT AND FUR CHARACTERS

Variables	Number	$\overline{X}$	$\overline{Y}$	r	Regression $b_{y.x}$ with standard error
Ear skin thickness (X) and ear length (Y)	158	1.36 mm.	9.28 cm.	0.13	.69± .43
Ear skin thickness (X) and birth wt. (size of pelt) (Y)	166	1.37 mm.	9.97 lb.	0.58	6.69± .73**
Ear skin thickness (X) and size of curl (Y)	166	1.37 mm.	5.07 Score value	0.11	1.20± .64
Ear skin thickness (X) and desirability (Y)	166	1.37 mm.	7.02 Score value	0.09	.98± .89
Ear skin thickness (X) and leather thickness of dressed pelts					
(a) At shoulder (Y)	70	1.41 mm.	1.42 mm.	0.26	.31± .14*
(b) At middle back (Y)	70	1.41 mm.	1.35 mm.	0.24	.23± .11*
(c) At loin (Y)	70	1.41 mm.	1.40 mm.	−0.21	−.26± .14
(d) At middle of left side (Y)	70	1.41 mm.	1.13 mm.	0.18	.16± .13
Length of ear (X) and size of curl (Y)	158	9.28 cm.	5.06 Score value	−0.19	−.37± .15*
Length of ear (X) and desirability of fur (Y)	158	9.28 cm.	7.01 Score value	0.31	.66± .16**
Birth wt. (size of pelt) (X) and size of curl (Y)	166	9.97 lb.	5.07 Score value	0.27	.25± .05**

* Significant.
** Highly significant.

The ear was inserted through this cylinder and held against the graduated scale with a pair of small tweezers, the jaws of which had a spring tension to hold them gently closed upon the ear. The lamb was held with its ear hanging in a natural position from the head and so that the ear was under the weight tension of only the tweezers weighing 10 grams.

To test the relationship between ear skin thickness of newly born lambs and the thickness of the skin covering their bodies or of their pelts a sample of 70 dressed pelts from the lambs in this study was measured for leather thickness. The leather measurements were made with the same micrometer and in the same manner as that described in measuring skin thickness on the ears of the live lambs. Measurements were taken at four points on the pelt; namely, the shoulder, middle back, loin, and at the middle of the left side.

Results

Ear skin thickness of 166 lambs ranged from 0.93 to 1.87 or an average of 1.37 mm. On the basis of this range, lambs with ear skin measuring 1.24 mm. or less were classified as thin skinned, 1.25 to 1.56 mm. moderately thick, and 1.57 mm. or more thick skinned.

Skin thickness was found to vary considerably over the pelt and to decrease from the back toward the belly area. There was a significant relationship between the skin thickness at the shoulder and middle back of the pelt with that of the ear skin thickness of the same lambs, as shown by the regression and correlation coefficients in table 1. Thickness of the skin at the middle of the left side, while not significant, indicated a positive relationship trend with ear skin thickness. Therefore, a thin ear skin was associated with thin leather in the pelt of the lamb.

The relationship between the desirability of the fur produced by the lambs and the thickness of their ear skin was not significant in this study. The fur of each lamb was assigned a desirability score by a committee of three judges as an over-all value representing the degree of fur quality. These scores were based on a judging standard ranging from 1 to 10, 1 being the most superior and 10 the most inferior in desirability. Although there was some tendency for lambs with thin ear skin also to have fur of high desirability, the frequency was not large. The results of Karakul fur grading work in the Union of Soviet Socialist Republics, however, as reported by Judin (1937), indicate that thin skin is associated with the best grade of pelts, very thin with the next, and thick with the least valuable.

Ear skin thickness and size of curl, as shown in table 1, have a positive relationship although not statistically significant. General observation of many pelts would indicate that thin skin and small curls tend to be associated. In this experiment sizes of curls were classified into small, medium,

large, and broad by eye judgments. For the purposes of statistical calculation these sizes of curls were assigned values of 3, 5, 7, and 9, respectively, on the basis of score values ranging from 1 to 10. The curl sizes were in general those defined by Plitt and Simmons (1941). They found in a preliminary study of curl sizes that these varied greatly on each pelt. Averages of 20 measurements taken on each of several representative pelts indicated that small curls were $\frac{1}{4}$ inch wide or less, medium curls $\frac{1}{4}$–5/16 inch, large curls 5/16–$\frac{3}{8}$ inch, and broad curls over $\frac{3}{8}$ inch wide. Kononova (1937) also found that large curls are associated with thick skin, and small curls with thin skin.

Birth weight of the lamb, which is indicative of the size of its pelt, and ear skin thickness were found to have a highly significant relationship. Data in table 1 indicate that there was a definite tendency for small lambs at birth to have thinner ear skin than large lambs. In like manner, the pelts of small lambs were thinner than those from large ones.

The relationship between birth weight (size of pelt) and size of curl was highly significant. Small pelts tended to have a fur pattern with small curls and large pelts had large curls. These results are in agreement with reports by Kononova (1937) that curl size shows a positive relationship with pelt size and weight.

There was a strong tendency for lambs having long ears also to have fur of higher desirability than lambs with short ears, as shown by the highly significant regression and correlation coefficients given in table 1. There was also a significant relationship between long ears and small curls.

Length of ear and ear skin thickness were not significantly related in this study.

The lengths of ears on 158 lambs ranged from 5.2 to 11.3 or an average of 9.3 cm. On the basis of the ear lengths of the lambs in this study, those with ears measuring 7.2 cm. or less were classified as short-eared; 7.3–9.3 cm., medium; and 9.4 cm. and over, long-eared. Reports of other investigators would indicate that there is considerable variation in ear lengths of Karakul sheep. Lush, Jones, and Dickson (1930) state that some of the Karakuls which they studied had ears 6 to 8 inches long, others 3 to 5 inches, and a few had stubs about 1 inch long which were classified as earless. No cases of earlessness have occurred in the Department's flock at Beltsville.

Summary and Conclusions

The ear skin thickness of 166 and the ear length of 158 purebred and crossbred Karakul lambs were measured to determine the relationship of ear measurements to pelt and fur characters. Methods of taking these ear measurements are illustrated.

Ear skin thickness of newly born lambs ranged from 0.93 to 1.87 mm.

There was a significant relationship between ear skin thickness of lambs and the leather thickness at the shoulder and middle back of their dressed pelts.

Ear skin thickness and birth weight of lamb (size of pelt) showed a highly significant relationship. There was a definite tendency for small lambs at birth to have thinner ear skin than large lambs, and pelts of small lambs were thinner than those from large ones.

Birth weight of lamb (size of pelt) and size of curl were also highly significant in relationship, as shown by the tendency for small pelts to have a fur pattern with small curls.

Although many of the lambs having thin ear skin also had fur of high desirability and small curls, these characters were not significantly related.

Lambs having long ears generally had fur of higher desirability than lambs with short ears. There was also a significant relationship between long ears and small curls.

The lengths of ears of newly born lambs ranged from 5.2 to 11.3 cm.

By taking simple measurements and selecting and mating together those individuals which had thin skins at birth, breeders may find it possible to develop strains of Karakul sheep capable of producing lambskins having light-weight leather.

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INFLUENCE OF THE SIRE ON THE BIRTH WEIGHT OF LAMBS

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THE importance of birth weight as a factor in sheep production has been demonstrated by Phillips and Dawson (1940). In a study of about 1800 lambs born during a 14-year period they found birth weight to be one of the factors that influenced survival, growth, and selection of breeding animals to be retained in the flock. A significantly higher proportion of the lambs that were heavy at birth survived than those lighter at birth. The relationship between weight at birth and weight at three months was definite and positive with less definite relationships at later ages. Lambs that were heavier at birth were also favored in the selection of breeding stock as shown by the number retained to 12 months of age.

The purpose of the present study was to measure the influence of the sire on the birth weight of lambs. Data were secured from a commercial flock established in 1937. The ewes were native Virginia ewes of variable breeding. The original flock, consisting of one hundred ewes, was divided into two groups, A and B, and bred to purebred rams as follows:

	1937	*1938*	*1939*	*1940*	*1941*
Group A	Hampshire	Southdown	Hampshire	Southdown	Hampshire
Group B	Southdown	Hampshire	Southdown	Hampshire	Southdown

Fifty additional ewes were purchased and added to the flock in 1939 with assignment to the above groups in equal numbers. Both groups of ewes were handled together in one flock except during the breeding season.

The rams used in the study were registered rams purchased from local breeders. They were good type commercial rams and considered to be representative of their respective breed as to size. Each year at breeding time the ewes were separated into their proper groups and two rams placed with each group. No attempt was made to differentiate between ewes bred to different rams of the same breed.

The reversal or "switchback" scheme of breeding provided for the estimation and control of variance associated with differences among the ewes in the analysis, if lambs from the same ewe were the same sex and either all singles or all twins. A comparison of male and female lambs born as twins indicated that males were slightly heavier, but the difference was small and

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relatively unimportant. The variance associated with the differences between twin and single lambs from the same ewe was controlled by using the data from only those ewes that produced three or more consecutive single or twin lambs. On this basis, thirty-nine ewes were available for this investi-

TABLE 1.—MEAN BIRTH WEIGHT IN POUNDS OF LAMBS SIRED BY HAMPSHIRE AND SOUTHDOWN RAMS IN A SWITCHBACK TRIAL

Group I

Age of ewe at first available lambing (years)	Number ewes in sub-classes	First lambing	Second lambing	Third lambing	Sub-class means
		Breed of sire			
		Hampshire	Southdown	Hampshire	
2	6	7.97	7.58	9.62	8.39
3	6	9.37	9.15	10.52	9.68
4[1]	6	10.53	9.87	11.25	10.55
Means	—	9.29	8.87	10.46	9.54

GROUP II

		Breed of sire			
		Southdown	Hampshire	Southdown	
2	6	9.05	10.70	10.58	10.11
3	6	9.80	11.48	11.23	10.84
4	6	8.87	10.82	9.92	9.87
Means	—	9.24	11.00	10.58	10.27

Both groups

Means	—	9.26	9.98	10.52	9.90

[1] This sub-class contained four ewes that were four-year-olds and two that were five-year-olds at the first available lambing.

gation. These ewes were arranged into sub-classes on the basis of age at the first available lambing, as follows:

1. Ewes with only three available lambings were classified into their respective sub-classes.
2. Ewes with four or five available lambings were classified by trial and error to supplement sub-classes obtained in the first step which contained less than six. Those with four available lambings were eligible

for use in one of two sub-classes and those with five available lambings were eligible for use in one of three sub-classes. For example: Ewe number 883, in group A of the original division, was three years of age when she lambed in 1938. She produced twins in 1938, 1939, 1940 and 1941 and was therefore available as a three-year-old in group I

TABLE 2.—INFLUENCE OF BREED OF SIRE ON BIRTH WEIGHT OF LAMBS
(Analysis of Variance)

	Degrees of freedom	Sum of squares	Mean squares
Ewes:			
Groups	1	14.52	14.52
Ages	2	23.25	11.63
Interaction between group and age	2	28.51	14.26
Within sub-classes	30	131.44	4.38
Lambing order			
Linear term[1]	1	28.38	28.38**
Quadratic term[2]	1	0.04	0.04
Interactions between linear term and:			
Group	1	0.12	0.12
Age	2	1.52	0.76
Interaction between group and age	2	0.18	0.09
Ewes within sub-classes	30	30.59	1.02
Interactions between quadratic term and:			
Group	1	26.46	26.46**
Age	2	0.55	0.28
Interaction between group and age	2	0.48	0.24
Ewes within sub-classes	30	53.30	1.78
	107	339.34	

[1] First lambing subtracted from third lambing.
[2] Twice second lambing subtraced from the sum of the first and third lambings.
** Highly significant: F value exceeds the 1% point of Snedecor's (1938) table of F.

or a four-year-old in group II. Her final assignment was to the latter sub-class.

By this method it was possible to classify thirty-six of the thirty-nine ewes into the groups and sub-classes shown in table 1.

The analysis of variance according to the method developed by Brandt (1938) is given in table 2. Highly significant values are shown for the linear term and for the interaction of the quadratic term with group.

On the average lambs from the same ewes were 1.15 pounds heavier at

the third lambing than they were at the first. It appears from the table of means that where the ewes were older at the first lambing, the difference in weight of lambs between the first and third lambings decreased. However, the analysis of variance shows no significant interaction between linear term and age. If there is any tendency for the birth weight of lambs to increase with the age of the ewe in a non-linear fashion between the ages of two and six, the departure from linearity is too small to be demonstrated by these data.

The difference attributable to breed of sire is identical with the interaction between the quadratic term and group. Lambs sired by Hampshire rams averaged 1.05 pounds heavier than those sired by Southdown rams, the difference being highly significant. In group I, Southdowns averaged one pound lighter than the trend for Hampshires; in group II, Hampshires averaged 1.09 pound heavier than the trend for Southdowns. The interaction between the quadratic term and ewes within sub-classes includes variance attributable to differences among rams of the same breed as well as that due to sex, year, and other uncontrolled factors. Since the sire could influence only the hereditary characters of the lambs, it appears certain that the rams within each breed transmitted characters to their lambs which influenced birth weight. Chapman and Lush (1932) in a study of the causes of genetic variability in birth weight in sheep found the variance associated with sire to be approximately 7.5 per cent of the total variance. Lush, Hetzer, and Culbertson (1934), studying the birth weights of pigs, found that total variance was reduced by about 7 per cent if the sire was held constant. In this study the total variance of the birth weight of lambs was reduced by 7.8 per cent by taking out the variance attributable to the single degree of freedom, breed of sire.

The estimate of the empirical difference in this study, which was associated with breed of sire, is about one pound, approximately 11 per cent, and indicates that the influence of the sire on birth weight of lambs is not in considerable.

Summary

1. Birth weights of lambs sired by Hampshire and Southdown rams were compared in a switchback trial.
2. An average annual increase of .63 pounds in birth weight of lambs as the ewe increased in age from two to six years was observed. No significant departure from linearity was shown by the data.
3. Lambs sired by Hampshire rams average 1.05 pounds heavier at birth than those sired by Southdowns, the difference being highly significant.

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MEASURING PERFORMANCE OF PROGENY OF RAMS IN A SMALL FLOCK[1]

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SELECTION of sires on the basis of the performance of their progeny is beset with more difficulties in small flocks than in larger ones where the numbers of females that can be placed in test pens is adequate to test several rams within a season.

In 1931 the Massachusetts Agricultural Experiment Station and the Bureau of Animal Industry of the United States Department of Agriculture began a cooperative study of performance in sheep. This continued through 1941. The purpose of the study was to obtain data on performance, and to use these data in locating superior sires and planning breeding operations in the flock. Analysis of the data collected indicates some of the difficulties involved when measuring performance of sires in small flocks. The findings may be useful to those who plan to base their selections on performance in flocks of similar size.

Material and Methods

The flock usually contained approximately 25 Shropshire and 25 Southdown ewes of breeding age. In addition to data on sex, date of birth, type of birth, sire and dam, the following data were obtained on each individual: birth weight, weight at weaning, slaughter score or grade at about 140 days of age,[3] and type score at about 240 days. Other data were also obtained, but were omitted from the present analysis. The items studied included those data which could be most easily obtained and used by the breeder.

Birth weight was recorded to the nearest one-tenth pound as soon as possible after birth. Lambs were weighed every two weeks up to weaning, and when not weighed at 140 days the nearest weight to this age was adjusted to 140 days using the method developed by Phillips and Brier (1940).

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[3] Slaughter lamb scores were obtained on all lambs at this time, even though they were not slaughtered until later, or were retained for breeding.

Slaughter grades were recorded by scores ranging from 1 to 19, 1 being the top score. (1 to 4 signifies "prime," 5 to 7 "choice," 8 to 10 "good," 11 to 15 "medium," 14 to 16 "common," and 17 to 19 "cull.") Type scores were recorded by scores from 1 to 5, being the most desirable. Each score was broken into 3 subclasses by the use of plus and minus signs, hence there were 15 classes. These type scores were coded from 5 to 19, 5 being used as top score merely for mechanical convenience in coding, to correspond with coding procedure on slaughter scores.

All progeny were adjusted to the basis of single ewe lambs, since the numbers of animals were small and it was not possible to make an adequate analysis of each separate group. The difference in size and development of males and females, or of singles and twins, prevents combining data from these different groups without making some adjustments, unless each ram's offspring contain equal numbers of each group. This has been demonstrated by Phillips and Dawson (1940) and a basis for making adjustments for differences in weight has been presented by these workers.

Data and Discussion

The numbers of lambs available for study and the average weights, grades and scores are given in table 1.

Relationships between Ewes and Their Offspring

The available dam-offspring pairs were studied to determine the average relationships between the records of the animals in each pair. At the beginning of the experiment, data were not available on many of the ewes in the flock, hence only those offspring that were from dams with records could be included. The numbers of pairs studied and the coefficients of correlation and regression are given in table 2. These were calculated on an intra-sire basis. With one exception, these coefficients are too small to be statistically significant, and indicate that the records of the dams were of relatively little value in indicating the merit of their offspring in the characters studied. These correlations are smaller than those reported by Briggs (1939) and Phillips, *et al.* (1940), and of about the same order as those reported by Rasmussen (1942).

Since the correlations presented in table 2 are all low, it is obvious that factors other than the heredity from the dam were affecting them. If no factor other than heredity from the dam affected these correlations they would be expected to be approximately .5. Such factors as the intrauterine environment, the milk production of the ewe, parasite infestation, yearly variations in weather conditions, and other environmental factors could

TABLE 1.—NUMBERS OF ANIMALS USED IN STUDY, AND THE AVERAGE WEIGHTS AND SCORES OF EACH GROUP OF ANIMALS

Lamb group	Birth weight		Weight at 140 days		Slaughter score or grade*		Type score**	
	Number studied	Ave. lbs.	Number studied	Ave. lbs.	Number studied	Ave.	Number studied	Ave.
Shropshire								
Single ewe	48	8.4	44	63.1	32	7.8	40	8.0
Twin ewe	83	7.4	65	53.9	50	9.5	62	8.9
Triplet ewe	4	5.6	4	58 2	4	7.5	4	7.8
Single ram	48	8.8	34	65.8	23	7.4	23	8.8
Twin ram	90	7.6	46	61.5	26	9.2	26	8.9
Triplet ram	2	5.7	1	50.0	1	8.0	1	7.0
Total	275	—	194	—	136	—	156	—
Southdown								
Single ewe	61	8.3	52	55.5	42	6.9	47	7.8
Twin ewe	66	6.5	52	48.9	44	7.7	51	8.8
Triplet ewe	6	4.9	4	42.3	1	11.0	4	8.8
Single ram	58	9.3	45	59.6	30	7.3	30	8.4
Twin ram	58	6.8	32	53.0	22	7.2	19	8.7
Triplet ram	3	4.7	1	46.0	—	—	—	—
Total	252	—	186	—	139	—	151	—

* 1 to 4 signified "prime"; 5 to 7 "choice"; 8 to 10 "good"; 11 to 13 "medium"; 14 to 16 "common"; and 17 to 19 "cull."

** 5 is top or ideal score in type and 19 the lowest possible score.

have had an effect. Chapman and Lush (1932) found that only 25 to 30 per cent of the variation in birth weight was hereditary. If the conditions they found were true in the present case, the correlation between birth weights of dams and offspring would be around .12 to .15. Phillips *et al.* (1940) have

TABLE 2.—RELATIONSHIPS BETWEEN DAMS AND OFFSPRING

Character studied	Shropshire			Southdown		
	Number of pairs	Correlation	Regression[1]	Number of pairs	Correlation	Regression[1]
Birth weight	150	.04	.05	107	.17	.20
Weaning weight	110	.04	.06	77	.02	.03
Slaughter grade	72	.04	.04	51	−.22	−.29
Type score	96	.06	.07	62	.11	.20

[1] Regression of offspring on dams.

shown that there were marked variations in body weight, fleece weight, and fleece length from year to year under conditions at Dubois, Idaho.

Adequate data were not available to make possible a valid adjustment of the present data for seasonal variations, hence some relationships that may have existed between dams and offspring may have been obscured by seasonable variations.

Differences between Sires

The groups of progeny sired by the different rams were compared to determine if differences existed in the ability of the rams to transmit the various characters to their offspring. The data in the previous section showed that the records on the dams were not significantly related to those of the offspring, with one exception (birth weight in Southdowns), and in this case adjustment of ram differences (by covariance) for differences in dams to which they were mated did not alter the results. Environmental influences, owing to seasonal variations and other causes, were apparently large enough to cover up the hereditary contributions of the dams to their offspring, and any further adjustments for differences in dams did not seem warranted in this phase of the analysis. This made feasible a comparison of the rams based on all their offspring, even though data were not available on all the dams. The results of this analysis are summarized in table 3. Inspection of this summary shows that the amount of variation between sires was statistically significant in one item (type score in Southdowns) and that it was highly significant in each of the other seven items that were studied. These results appear to indicate that there are definite possibilities of selecting rams that are superior sires, as judged by birth weights, weaning weights, carcass grades and type scores of their offspring. The variations observed are sufficiently large to be of considerable economic importance. For example Shropshire ram 3938 sired lambs that averaged 59.0 pounds at 140 days while ram 553's lambs averaged 72.2 pounds. In addition to the extra weight advantage of 13.2 pounds per lamb, the offspring of 553 averaged 2.86 points higher in grade. In actual slaughter grade the two groups were graded near the center of "Good" and "Choice" grades, a difference of one grade in favor of ram 553. However, these findings cannot be accepted as representative of the true picture, since differences owing to environment in different years could not be separated from differences owing to sires, and this point is discussed in more detail later.

The rams were also studied on the basis of a comparison of the records of their offspring and the dams of these offspring. In only four cases out of 52 (13 ram progeny groups and 4 comparisons per group) were the records of offspring superior to those of the dams. This is an excellent demonstration

of the problem which every breeder faces in attempting to select superior animals. In the selection of breeding animals the animals that are superior in weaning weight, slaughter grade, and type score are naturally the ones that are retained. Phillips and Dawson (1940) have demonstrated that lambs that are heavy at birth have a better chance of being selected as breeding animals, and these and other workers have shown that there is a positive relationship between birth and weaning weights. A comparison of the average weights and scores of dams (adjusted to single ewe lamb basis) with the average weights and scores of single ewes showed that the dams are above the

TABLE 3.—SUMMARY OF ANALYSES OF DIFFERENCES BETWEEN SIRE PROGENY GROUPS, DISREGARDING THE EFFECTS OF YEARLY VARIATIONS

Shropshire

Source of variance	Character studied							
	Birth weight		Weaning weight		Slaughter score or grade		Type score	
	df[1]	Mean square	df	Mean square	df	Mean square	df	Mean square
Between sires	5	12.47**	5	582.25**	5	29.53**	5	7.23**
Within sire groups	269	1.90	188	72.49	130	4.09	150	1.68
Southdown								
Between sires	9	5.89**	9	362.69**	8	17.24**	9	5.49*
Within sire groups	242	1.84	176	67.68	130	4.23	140	2.58

[1] Degrees of freedom. * = significant (P = .05). ** = highly significant (P = .01).

average of the population in all cases. On the average, one would expect that individuals selected on the basis of their phenotypes from the better portion of a population would produce offspring only slightly better than the average of the original population. Since the dams are selected from the better portion of the population, only a very exceptional ram would be able to sire offspring equal to the dams. (Shropshire ram 852 appeared to be just such a ram. His offspring more nearly approached their dams in birth weight than did the offspring of any other ram, and they were superior to their dams in weaning weight, slaughter grade, and type score. Thus, this ram accounts for 3 of the 4 cases, mentioned earlier in this paragraph, in which offspring were superior to their dams.) This is true because the characteristics being measured are not entirely hereditary. The smaller the fraction of the variance which is additively genetic, and the more intense the selection of the dams,

the more conspicuous this phenomenon will be. When only a part of the phenotypic variance is additively genetic, the breeding values of phenotypically selected individuals regress toward the mean of the population from which they are taken.

TABLE 4.—SUMMARY OF ANALYSES OF DIFFERENCES BETWEEN YEARS AND BETWEEN SIRE PROGENY GROUPS WITHIN YEARS

Source of variance	Characters studied					
	Birth weight		Weaning weight		Type score	
	df[1]	Mean square	df	Mean square	df	Mean square
Shropshire						
Between years	4	28.64**	4	361.98**	3	7.30**
Between sires within years	5	11.85*	5	52.19	4	3.15
Remainder	178	4.50	117	82.93	82	1.52
Southdown						
Between years	3	4.02	3	1182.27**	3	2.84
Between sires within years	4	3.29	4	14.01	4	4.29*
Remainder	138	1.80	101	56.14	81	1.50

[1] Degrees of freedom. * = significant (P = .05). ** = highly significant (P = .01).

The analysis of sire differences given in table 3 does not take year to year variations into account, and, as was pointed out earlier, there were not sufficient data available to bring this source of variation under statistical control for the entire population studied. However, sufficient data were available on the progeny of rams whose use overlapped in one or more years to make possible a rough approximation of the importance of year to year variations for birth weight, 140-day weight and type score. Slaughter grade could not be included because of insufficient data. A summary of the analyses is given in table 4. The results indicate that there were highly significant yearly variations in all three characters studied in the Shropshires and in weaning weight in the Southdowns. A comparison of the significance of variations between sires with those given in table 3 shows that in four cases the result changed from highly significant to not significant, in one from highly significant to significant, and in one the level of significance did not change materially.

The results given in table 4 suggest strongly that much of what was supposed to be difference between sires in table 3 was caused by differences in

environmental conditions from year to year. To a considerable extent, differences in sires coincide with differences between years, in table 3. These results indicate the importance of making comparisons of rams within a given year, unless there is some adequate provision for adjusting year to year differences.

TABLE 5.—DIFFERENCES NECESSARY TO BE SIGNIFICANT (P=.05) WITH VARIOUS NUMBERS OF OFFSPRING, EACH SIRE HAVING THE SAME NUMBER OF OFFSPRING IN A COMPARISON

No. of offspring from each ram	Birth weight		Weaning weight		Type score	
	Shropshire	Southdown	Shropshire	Southdown	Shropshire	Southdown
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Score*	*Score*
2	4.2	2.7	18.0	14.9	2.5	2.4
3	3.4	2.2	14.7	12.1	2.0	2.0
4	3.0	1.9	12.8	10.5	1.7	1.7
5	2.6	1.7	11.4	9.4	1.6	1.5
6	2.4	1.5	10.4	8.6	1.4	1.4
8	2.1	1.3	9.0	7.4	1.2	1.2
10	1.9	1.2	8.1	6.6	1.1	1.1
12	1.7	1.1	7.4	6.1	1.0	1.0
14	1.6	1.0	6.8	5.6	0.9	0.9
16	1.5	0.9	6.4	5.3	0.9	0.9
18	1.4	0.9	6.0	5.0	0.8	0.8
20	1.3	0.8	5.7	4.7	0.8	0.8
30	1.1	0.7	4.7	3.8	0.6	0.6

The variation within sires, as determined by analysis of variance, was used to determine for the various characters the differences that would be necessary to be significant, using the method described by Hetzer and Brier (1939). This makes possible a rough estimation of the number of offspring necessary to test a ram. These results, based on variation within sire, but without correction for year to year variation, indicated that considerable information is gained per each additional offspring up to 8 or 10. From this point the decrease in information per offspring added is fairly rapid, and little information is added per offspring beyond 15. When studied on the basis of variation within sire in the data where adjustment could be made for yearly variations the results were quite similar, except that on this basis the difference necessary to be significant was somewhat lower for type score and weaning weight. The necessary difference did not change materially for birth weight. Differences necessary to be significant (P=.05), with yearly variations controlled, are presented in table 5, assuring equal numbers of offspring for each of the two sires being compared.

Discussion

Many purebred flocks contain only 25 to 40 ewes of breeding age and only one or two stud rams at any one time. This situation exists in many agricultural college flocks as well as in private flocks, and under such conditions it is difficult to carry out a constructive breeding program based on the performance of sire progeny groups.

It is sometimes possible to obtain a sire of high merit on the basis of observation of his progeny, but such sires are seldom for sale until several years of age, when the breeder who has tested them has used them to the fullest extent possible. When untried sires are used the breeder is fortunate to obtain a sire that will maintain the level of merit in his herd and exceptionally fortunate if that level is raised to any marked extent. If the sire is satisfactory his use can be continued and his better offspring can be incorporated in the breeding flock as replacements, but if unsatisfactory the ram will be discarded along with all or most of his offspring. Thus the breeder loses valuable time in the development of his flock.

If the breeder desires to carry out a routine program of testing young rams, selected either from outside or within his flock, the minimum requirement of breeding ewes would be approximately 50. Of these, 20 of the best ewes might be set aside as the stud flock to be bred to a sire of known merit and two groups of 15 each, divided to be of approximately equal merit, would be bred to young, untried sires. These would be selected phenotypically and should represent the best individuals available to the breeder in terms of the characteristics being stressed in the flock. Thus the progeny of the two rams being tested could be compared with each other and with the progeny of the stud ram, all the lambs being raised under comparable conditions within the same season. Two new rams would be tested in the second season and the stud ram would be used again on the main flock or would be replaced by one of the young tested rams, if his progeny were sufficiently good to justify a change. Thus there would be a ram carrying over from the previous year whose progeny would give some basis for evaluating the effect of year to year differences in environment. Replacements in the ewe flock would be selected only from the progeny of the stud ram and of young rams that prove of sufficient merit to be retained as stud rams, and selection would be based on the economically important characters that are being stressed in the particular flock and breed.

This breeding system provides for the testing of young sires and eliminates the danger of making errors through the use of rams in the stud flock before data are available on the quality of their offspring. It should be pointed out, however, that this system does not guarantee a rapid rate of improvement because the number of rams that can be tested at one time is

obviously low and the rate of progress probably will be only a little faster than that which is possible with phenotypic selection alone.

Summary and Conclusions

Data were collected on sheep in the Massachusetts State College flocks (Shropshire and Southdown) from 1931 to 1941, inclusive. The data on birth weight, weaning weight, slaughter score or grade (at 140 days) and type score (at 240 days) were analyzed to determine the possibilities of measuring performance of rams in small flocks.

Relationships between dams and their offspring, as measured by coefficients of correlation and regression, were low and none were large enough to be statistically significant. Adequate data were not available to make possible a valid adjustment for seasonal (year to year) variations, hence some dam-offspring relationships may have been obscured.

Differences between sires were significant or highly significant when all the data were studied without regard to seasonal (year to year) variations. A portion of the data could be used in an analysis to determine the relative importance of seasonal variations and the findings strongly suggest that much of the supposed difference between sires was caused by differences in environmental conditions from year to year. These results indicate that it is desirable to make comparisons of rams only when tested in the same year, unless adequate controls are available to serve as a basis for adjusting for seasonal differences.

A study of the number of offspring necessary to test a ram indicated that considerable information is gained per additional offspring, up to 8 or 10. Beyond this point the decrease in information is fairly rapid and relatively little is added per individual beyond 15.

A procedure is outlined for testing rams in small flocks.

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A NOTE ON THE EFFECT ON THE KIDNEYS AND LIVERS OF FEEDING UREA TO STEERS FATTENING IN DRY LOT AND ON PASTURE[1]

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Introduction

THE Department of Animal Husbandry of the University of Hawaii has carried out feeding experiments during a two-year period in which urea[5] has been partially or wholly substituted for the nitrogenous supplements ordinarily included in steer fattening rations. The use of urea for replacement of the usual nitrogenous feeds of the ratios of cattle has been reported in the literature by Work and Henke (1939) and by Hart *et al.* (1938) and by others. Work and Henke reported no unfavorable results of feeding urea but Hart and his co-workers reported that when urea was fed to cattle at the rate of 4.3 per cent of the dry matter of the ration, diuresis resulted and kidney damage was found at autopsy. They reported also that kidney damage, though still apparent at the 2.8 per cent level, was not found when urea replaced smaller quantities of the protein portion of the ration. The observations of Hart and his co-workers indicated that kidney damage resulted from the feeding of urea at high levels but kidney damage ceases to occur at some point below the level where urea forms 2.8 per cent of the dry matter of the ration. The present paper presents observations on the condition of the kidneys and livers of steers fed urea at levels below 2.8 per cent of the dry matter of the ration.

Data and Discussion

A series of feeding experiments in beef husbandry have been carried out by the Animal Husbandry Department of the University of Hawaii and the results of the experiments will be presented in detail elsewhere. One of the feeding trials included the feeding of urea to steers fattening in dry lot while another involved the feeding of urea to steers fattening on pasture. Only observations on the condition of the livers and kidneys of animals on

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[5] Urea or Uramon (trade name) is a du Pont product commonly used as fertilizer in the production of sugar cane.

those two feeding trials are included here. Accurate group records of all feed intakes were available for the animals fed in dry lot and the details of that feeding trial are presented in table 1. The known values for the food intake of animals on the pasture feeding trial are also presented in table 1 and it will be noted that the absolute amount of urea consumed by lots 2

TABLE 1.—A SUMMARY OF THE FEED INTAKE OF THE STEERS ON DRY LOT AND ON PASTURE

Experiment	Lots	Animals per lot[1]	Initial weights	Actual rate of feeding per head per day					Days on test	Urea as per cent of dry matter of ration
				Strip cane[2]	Uramon	Cottonseed meal	Molasses	Pasture		
			lbs.	lbs.	lbs.	lbs.	lbs. (ad lib)			
Dry lot	1	5A 4H	473	18.7	—	3.67	10.7	—	244	—
	2	5A 4H	472	19.4	0.15	2.95	11.9	—	244	0.88
	3	5A 4H	471	18.5	0.35	2.15	11.8	—	244	2.29
Pasture	1	10H	761	—	—	—	7.2	ad lib	186	—
	2	10H	757	—	0.18	—	7.5	ad lib	186	0.97[3]
	3	10H	757	—	0.35	—	7.2	ad lib	186	1.91[3]
	4	10H	761	—	—	0.85	7.2	ad lib	186	—
	5	10H	760	—	—	1.64	7.1	ad lib	186	—

[1] Letter A refers to Angus steers; letter H refers to Herfords.

[2] Strip cane is a byproduct resulting from the harvesting of sugar by a "grab" or other system. The stalk, with leaves still attached, is brought to the mill; the leaves and leaf sheaths are stripped from the stalks by a series of rapidly revolving rollers, and the resultant material is commonly known as "strip cane." It includes in addition to the green cane tops of leaf sheaths any dry cane trash that may not have been destroyed in the burning of the fields previous to harvesting. It may also include large quantities of earth particularly if the harvesting is done during rainy weather and washing facilities are inadequate. The green cane tops may be partially dried, depending on the interval between burning the field and bringing the cane to the mill.

[3] An estimated figure for purpose of reference only.

and 3 is practically the same as that of the animals of lots 2 and 3 of the dry lot group.

An accurate figure for the dry matter intake of the animals on the pasture feeding trials can not be determined. Garrigus and Rusk (1935), however, have made such determinations under controlled conditions for grazing

steers of weights similar to those on our pasture feeding trial. Their work indicates that such grazing steers consume dry matter to the extent of about 2 per cent of their live weight. However, it is a well-known fact that pastures vary widely in their dry matter content according to the species, the storage of maturity and the climatic conditions prevailing during growth. Ripperton *et al.* (1933) and Edwards and Goff (1935) have presented figures for pasture grasses in Hawaii. Employing the values presented by the workers indicated above, an estimate can be made that the lot 2 steers of the pasture feeding trials were fed urea at the rate of 0.97 per cent of the dry matter of the ration while lot 3 steers received urea at the rate of 1.91 per cent of the dry matter of the ration.

No differences between the gains in liveweight of the animals of the first and second lots of the dry lot feeding trial were observed. However, the third lot of this feeding trial was definitely inferior to first and second lots in gain in weight. Gain in weight of the various lots of animals on the pasture feeding trial was similar. No diuresis was observed in any of the groups but, due to the average molasses intake of 10.7 pounds in lot 1 and 11.8 pounds per head per day in lots 2 and 3, diarrhea was evident in all animals of the dry lot test.

All the animals of these feeding trials were slaughtered and all internal organs of the animals were carefully examined.[6] Gross abnormalities were absent. Portions of the kidneys and livers of three animals selected at random from each group of animals in the dry lot experiment and of two animals of each group of pastured steers were fixed in formalin and preserved for histological study. Sections of the livers and kidneys were stained with hematoxylin and casein, or with Dominici's stain or with Sudan IV and methylene blue. All preparations revealed normal histology, cellular changes, connective tissue infiltrations or fatty infiltrations being absent.

Summary and Conclusions

These studies show that urea fed for long periods of time to steers under dry lot management at the rate of 0.88 and 2.29 per cent of the dry matter of the ration does not cause liver or kidney damage. They also show that urea, when fed to steers on pasture at the rate of 0.18 and 0.35 pounds per head per day, and as complete replacement for cottonseed meal supplement, does not cause liver or kidney damage. These observations are significant in view of the fact that Hart and his co-workers have shown that kidney damage is present when urea is fed at the rate of 4.3 per cent of the dry matter of the ration and is also apparent when it is fed at the 2.8 per cent

[6] Examinations were made by Dr. Ralph A. Parsons of the U. S. Bureau of Animal Industry.

level. This suggests that the harmful level of urea feeding for cattle may be between 2.29 and 2.8 per cent of the dry matter of the ration. This conclusion cannot be extended to all ruminants because Harris and Mitchell (1941) have shown that when urea is fed to wethers at the rate of 3.15 per cent of the dry matter of the ration kidney damage does not occur.

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NEWS AND NOTES

In accordance with a recent decision of the Executive Committee, the thirty-sixth annual meetings of the American Society of Animal Production will be held in Chicago, on November 30 and December 1, 1943. Members are urged to send titles of papers to be presented at these meetings to the Secretary, Dr. A. D. Weber, Kansas State College, Manhattan, Kansas, as soon as possible in order that program plans may be formulated without delay. Abstracts of all papers *must* be in the hands of the Secretary by September 15. Titles and abstracts received after this date cannot be included in the program and abstracts cannot be published. The abstracts should be typed in the form used for abstracts in the November, 1942, issue of the Journal and must not exceed 250 words (usually one page or less, double-spaced). *Please check items 5 and 6 of "Information for Contributors."*

The North Atlantic Section has elected the following officers for 1943: W. B. Young of the University of Connecticut, president; James G. Watson of the New England Homestead, vice-president; V. A. Rice of Massachusetts State College, secretary-treasurer. R. A. Murdock of Middlebury, Vt., and John Miller of Cornell University have been elected to the executive committee.

Biological Abstracts has recently announced the publication of Section G which will consist of abstracts on the various biological aspects of food technology, food microbiology, human and animal nutrition, vitamins and the scattered biological literature that pertains to research on nutrition and foods. It will consist of ten abstract issues a year plus the index issue to the complete edition of Biological Abstracts. The price will be $6.00 a year and inquiries should be sent to Biological Abstracts, University of Pennsylvania, Philadelphia.

S. H. Work has resigned from the faculty of the University of Hawaii and is now animal husbandman with the U. S. Department of Agriculture's Office of Foreign Agricultural Relations. He will be stationed in Nicaragua and will help the Government of that country set up a research program in animal husbandry.

H. J. Brooks, formerly animal husbandman at the Insular Agricultural Experiment Station in Puerto Rico, is now animal husbandman in the Office of Foreign Agricultural Relations. He will be stationed in Peru where he will act as advisor to the Peruvian Government on animal husbandry problems and will have charge of the animal husbandry work at the experiment station which is being set up at Tingo Maria, Peru.

H. H. Leveck, head of the animal husbandry department at Mississippi State College is on leave for military duty, with the title of Lieutenant Colonel.

Lorin E. Harris, formerly with the Arkansas Experiment Station, has taken a position with the United States Department of Interior, with headquarters at Cornell University. He will work on the nutrition of fur-bearing animals.

S. S. Wheeler of the University of Wyoming completed requirements for the Ph.D. degree at Iowa State College in July, 1942.

A. T. Semple of the Agronomy Division, Soil Conservation Service, is on leave for a special assignment with the Board of Economic Werfare. He will be stationed in Madagascar and will work in the interest of increased food supplies for the United Nations.

Miss Jessie Alice Cline has succeeded Miss Inez Wilson as head of the department of home economics of the National Live Stock and Meat Board, Chicago.

E. E. Grissom, assistant extension animal husbandman, Mississippi State College, is now in the U. S. Army.

Melvin Hazaleus of the Colorado State College animal husbandry staff has entered officer's training school for the U. S. Marine Corps.

E. W. Sheets is now associated with the National Grange, with headquarters in Washington, D. C.

Clinton K. Tomson, formerly western field representative of The Shorthorn World, succeeds H. J. Gramlich as secretary of the American Shorthorn Breeders' Association on January 1, 1943.

W. J. Kennedy, vice-president and sales manager of the Anchor Serum Company, St. Joseph, Missouri, and widely known livestock judge, died on November 12. He was born in Ontario, Canada, and was for years connected with the animal husbandry departments of the Iowa State College and the University of Illinois.

S. H. Starr, director of the Georgia Coastal Plain Experiment Station, Tifton, Georgia, died recently.

E. H. Hughes of the University of California staff in animal husbandry and Guy A. McDonald, extension animal husbandman, South Dakota State College, were members of Swift & Co.'s educational tour in September and October, visiting Chicago, New York, Boston, Philadelphia, Baltimore and Washington.

The Animal Husbandry Department, N. Carolina State College, University of N. C., Raleigh, reports recent additions to the staff: Associate Professor D. E. Bailey in charge of Meats Research; Miss Hartlee Baxley, Assistant in Animal Nutrition; and Mrs. Mary Alexander Monteith, Assistant in Dairy Investigations.

Five members of the staff of the Animal Husbandry Department, of the Agricultural and Mechanical College of Texas, have reported for duty in the U. S. Armed forces during the last year: R. J. Von Roeder as Captain on foreign assignments; W. W. Bailey as Captain on special research assignments on Meats; B. R. Dane has become an Ensign in the Navy; and W. W. Warren and Stanley C. Stribling have entered officers training in the Marine Corps.

C. D. Gordon from the poultry office at Beltsville, Md., succeeds W. F. Ward at Chinsegut Hill Sanctuary, Fla.

Duane Clark, eastern field representative of the American Aberdeen-Angus Association with headquarters at Frederick, Md. is now in the armed forces.

C. L. Hill, extension animal husbandman, Louisiana State University, is now in military service.

Eugene Bertone, formerly with Dr. J. I. Hardy at Beltsville, is now wool technologist at the Colorado Agricultural College.

A. A. Speelman, formerly in charge of dairy extension at the University of Kentucky, reported on January 1 at Pullman, Wash., to become Assistant Professor of Dairy Husbandry and Assistant Dairyman to succeed J. C. Knott recently made Director of Extension in the same institution.

Paul P. Hite, extension sheep specialist at the University of Tennessee, was elected vice-president of the American Southdown Breeders Association at the last annual meeting in Chicago.

G. Bohstedt, has been made head of the animal husbandry department, University of Wisconsin, to succeed A. L. Darlow, resigned to accept a similar position at Oklahoma A. & M. College.

A. Burr Ross, has been promoted to asst. professor of animal husbandry, University of Wisconsin, and Burl Winchester is now in charge of sheep husbandry.

H. J. Gramlich was appointed general agricultural agent of the Chicago North Western Railway, effective February 15, 1943, with headquarters at Chicago. Gramlich was formerly secretary of A.S.B.A.

G. A. Tucker, Asst. Animal Husbandman, Florida Range Cattle Experiment Station at Limestone, is now on leave for military service.

D. C. Gaylord, was appointed extension animal husbandman in the Connecticut Extension Service, August 15, 1942, to succeed W. B. Young.

Edgar Martin has been appointed assistant in animal husbandry and assistant animal husbandman, University of Arkansas.

R. B. Cathcart, assistant professor of Animal Husbandry at Kansas State College, has been granted leave to enter military service.

Stanley P. Marshall has been appointed assistant in animal nutrition on experiment station staff, University of Florida.

M. H. McDonald, Assistant Professor at North Dakota Agricultural College, is now full time extension animal husbandman in the same State.

New Mexico—College Station—K. A. Valentine has been appointed assistant animal husbandman.

Pennsylvania—Staff members in military service are Alex Block and A. L. Voris, assistant professors in animal nutrition; C. E. French, instructor in animal nutrition.

Vermont—N. N. Allen has been appointed assistant professor of dairy production and assistant animal and dairy husbandman.

Don W. Chittenden, formerly with the Corn Belt Dailies, is now a member of the staff of The American Hereford Journal, Kansas City, Missouri.

H. B. Osland has resigned his position as head of the animal husbandry department, Colorado Agricultural College, to become manager of a purebred cattle herd at Steamboat Springs, Colorado. R. C. Tom is now acting head of the Department.

Ivan Watson, assistant professor of animal husbandry, Colorado State College, has resigned to accept private employment.

A. Lamar Esplin of Utah has accepted an appointment to do research and extension work in sheep husbandry at Colorado State College. He has been doing graduate work at Texas A. & M. College.

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